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MARITIME ATMOSPHERE SALT LOAD MONITORING SYSTEM.(U)
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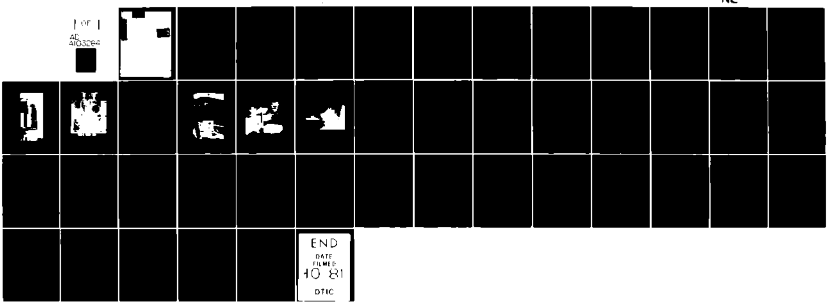

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An automatic atmospheric salt load sampling device was designed and deployed on shipboard, traversing the North Atlantic from January to June, 1980. Derived from our Automatic Radon Counter, the device has operated unattended for up to five weeks at sea. Salt load samples were analyzed in the laboratory, while NRL sensors provided data on atmospheric radon concentration, wind speed and direction, ship's speed and heading and GMT. All data sources were polled and recorded at the time of sample acquisition
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20. ABSTRACT (continued)

by an NRL designed hard-wired digital data handling system. Electronic circuit diagrams for the control and data handling units are shown and described, for the purposes of construction and maintenance of a system.

TABLE OF CONTENTS

MARITIME ATMOSPHERE SALT LOAD MONITORING SYSTEM

INTRODUCTION

The long term goal of our aerosol research at NRL is to acquire real-time information and establish a statistical data base on atmospheric salt loading over the oceans under various conditions during all seasons of the year. We have been mainly interested in a device (Bressan, 1979) to operate unattended under almost any weather conditions, sample dry aerosols, rain or fog, give a real-time indication of the total salt load found in each of at least three broad particle size ranges, and still retain a portion of each sample for later chemical analysis in the laboratory. The collection of abundant ancillary data would be essential for interpreting the chemistry of the collected aerosols, and for the construction of predictive models.

An interim goal connected with the development of test criteria for sea-going gas turbine engines has been to devise a reliable aerosol collector. (The unattended unit collects marine aerosols on Hollingsworth & Vose HE1022 filter tape, as for automatic radon (Rn) collection and counting (Larson and Bressan, 1978). Although atmospheric salt loads are determined in the laboratory, all other data are collected and recorded in real time. Since much less salt load data is available for the winter months, this system was designed to fulfill our need for all weather, unattended shipboard sampling. It was deployed aboard the GTS W. M. CALLAGHAN from January to June 1980 in a relatively successful effort to collect winter salt load data over the N. Atlantic during repeated crossings from Bayonne, NJ to Bremerhaven, F. R. Germany and return. The experiment designers rode the ship for the first three-week round trip, but the equipment recorded data unattended throughout its entire deployment. The purpose of this report is to describe the sampling and data collecting system, including the improvements made during some of the port calls throughout the experiment.

THE SYSTEM

Successful data system operation depends upon the factors of coordination, timing, and reliability. A multiplexer (Mux), a printer and a clock form the nucleus of our data gathering/recording system, with the sensor systems being plugged into the data bus at any of seven data input ports. Our data input devices are the <u>A</u>utomatic <u>R</u>adon <u>C</u>ounter and <u>A</u>erosol <u>S</u>ampler (ARCAS), wind speed and wind direction sensors, and thumbwheels for dialing in the ship speed and heading. A block diagram of the system is shown in Figure 1, for reference in the following discussion.

Data recording is coordinated by the multiplex controller. Operating as an interrupt system, it scans all data input ports in succession, upon request, and records the presented data either as per instructions

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from the port logic of the data supplying units, or as directed by prearranged hard wiring. All control circuits are hard wired, with variations in programming being accommodated by DIP switches. This system does not require operator direction at start-up. Although it is hard wired, the multiplexer is flexible enough to accept control signals from an external, higher-level coordinator, such as a computer or microprocessor.

Appropriate timewise coordination of the data-gathering devices (simultaneity) is accomplished in two ways. All durations (except within the multiplex controller) are determined by counting the power-line frequency of 60 Hz, so there will be no long-term drifts between separate units. The resetting of short interval timers can be triggered by the multiplex controller during the scan of a unit.

A major requirement of the data recording system is accurate time recording of all events, to permit precise temporal correlation of data. For this, our system includes a crystal-controlled digital clock (with an eight-hour battery reserve) that displays day of the year, hour, minute and second, and outputs them for recording. The data are recorded by a Datel thermal printer which lists one six-character number (hexadecimal or decimal, with sign and decimal point) per line.

Reliability of the system results from careful design and the use of high-quality components in the construction of each individual unit. Purposely designing for worst-case conditions is absolutely essential. For example, after a power failure, the whole ARCAS system is self starting, and after no more than two operating cycles all data supplying units will be in syncronization with each other and the data recorder, without operator intervention. Since the system gives a printout at start-up after a power interruption, and since the clock (being battery sustained) is always correct, any power failures are accurately documented in the printout.

Attention to such features as these has allowed us to construct an aerosol sampling and data-logging system for long-term survey service which does not need a trained scientist in attendance, and which can operate for four weeks between servicings. On the other hand, catastrophic failures of data acquisition could occur and go unnoticed, so attendance is recommended for one-time deployments. We were fortunate that officers on watch aboard the CALLAGHAN volunteered to enter navigational data via thumbwheels located on the bridge. (Because entry delays of up to 20 minutes are not serious and only one or two changes per day were necessary, routines on the bridge were not disrupted.) Otherwise, the automatic recording of ship's speed and heading would require tapping into the ship's servo system with a dedicated unit from which the data could be acquired.

SYSTEM OPERATION

The multiplex unit was designed to supply data to the printer and to manage the printout format. One feature is that the unit requesting a scan can designate that all valid data be printed or that only its own data be printed. During a data scan the multiplex controller normally has the I/O board accept and print two successive lines of up to eight characters each from each data port in turn. However, the two line acceptance sequence

can be repeated any number of times before the controller advances to the next port. This feature allows in-putting multiple lines of data from a single unit (such as the transmission of a spectrum), or the merging of data from many units (by a properly interfaced expander) through one data port. An operator can also request a printing of all valid data by a pushbutton, which also causes a flag (decimal point) to show in the printout as noted in Figure 2.

The "zeroth" input port is dedicated to the clock, with ports 1-7 used for data. The radon counts are the first line of port one, ship's speed and heading of three characters each form the 2nd line of port one, and the relative wind speed and direction of three characters each and a $\pm$ sign form the 1st line printed for the 2nd data port. This arrangement is shown in Figure 2.

In general, each of the data sensors accumulates readings under guidance of its own control system. When the data has been accumulated its control system may request a scan to get the data printed, or hold the data until the next scan occurs, then start accumulating a new data set. The wind speed unit holds the data using a digital voltmeter (DVM) as a memory register, but also immediately starts acquiring a new data set in its integrator. After each acquisition, the DVM display/output register is updated to hold the new data. In this way a scan can come at any time and get the most recent data, the only restriction being that updating is not allowed during a scan.

As seen in Figure 1, each data-supplying unit has an associated Mux Interface/Port Logic board (of 4 to 7 integrated circuit (I.C.) chips). This board interprets communication between the data supplying unit and the Mux controller, and encodes and transmits the data down the 14-line data bus in a sequence of four-bit, parallel, binary characters. The other ten bus lines are used for port and character selection (five lines), and specific communications (hand shaking) and control (five lines). These details are given in Appendix I.

The Datel DPP-7 printer records only the final six characters of an eight-character line transmitted on the data bus. Therefore, one character is available to transmit $\pm$ sign and decimal point information, while the other is used as a convenience channel to transmit housekeeping information. However, in another application, the "extra" character could contain data.

Figure 3 shows the indoor unit mounted onboard the CALLAGHAN. Plainly visible are the wind speed and direction displays, crystal controlled clock display, ARCAS control panel, navigation data thumbwheels, and Datel printer with hand operated take-up spool. The small button on the panel beneath the printer is for an observer to call a scan. This enables recording manual data changes when made and time documenting notes written on the printout. The top of the unit is fitted with a flat tray which is used as a writing surface for the officers on watch.

THE SENSORS

The on-deck sampling unit (shown in Figure 4) is an Automatic Radon Counter (Bressan and Larson, 1979) modified and updated to also collect salt samples under winter weather conditions. A PVC box was constructed to house all on-deck components (tape transport, aspiration motor, motor controllers, radiation detectors, pulse amplifiers and transmitters, power supplies and calibration electronics). This box has a Lucite door and air inlet tube, which are sealed to it with "O"-rings, and is also provided with a drain hole in case of leakage.

The air inlet shown in Figure 5 was designed to keep out rain and large fog drops, yet allow smaller droplets and aerosols to enter from any direction at up to about 60 knots wind speed. Estimations of the most likely air flow patterns with computations (after Hochrainer, 1978) of viscous drag forces indicate that at 60 knots, salt particles up to 40 µm diameter should follow the air flow pattern down the inlet tube, while particles of 100 µm diameter would certainly impact on the opposite inner wall of the vertical inlet tube. On the CALLAGHAN, the inlet was mounted approximately 2.4 m (8 feet) above deck level, as seen in Figure 6. This was to put it into the main flow of ambient air located above a band of semi-stagnant eddies circulating just above deck level.

A 96-watt heating tape was wrapped around the vertical metal section of inlet tube just above the filter to dry out droplets which may be collected during heavy fogs (and to dry the filter paper if necessary). The air exhaust opening is protected by a deflector which turns the air flow downward and shields the rear of the motor from rain.

This radon unit uses a pair of counting tubes and an improved filter paper transport. The solid state sequence controller, counters, and Triac motor control units were redesigned to eliminate the previously used electromechanical timers and relays. The circuit diagrams with their description are presented in Appendix III. It is noteworthy that this unit can be used with the multiplexed system or may directly operate a dedicated printer. It can also accept some external controlling signals, as could be provided by a microprocessor.

During operation, a 20-minute duration sample (of Rn and salt) is acquired every 90 minutes, and the Rn daughter decay is counted for a series of 10-minute intervals until the next sample is ready to begin counting. The count total for each 10-minute interval is printed on paper tape, with the record for the first 10-minute count interval including lines for Julian day, time, Rn counts, ship's speed and heading, and relative wind speed and direction. Figure 2 illustrates the printout of a typical sample. Note the + sign as a flag on the first Rn count and that all subsequent counts, taken and printed at 10-minute intervals, do not include the + sign or the ancillary data which describes sample collection conditions.

The salt load sample is collected in a (more or less) visibly darkened spot on the filter paper where radon daughters are collected. Since the first radon count for each collected sample is flagged with a + sign preceding it, the number of flagged counts corresponds to

the number of dark circles on the filter paper. From that, the collection time of each Rn plus salt sample can be determined when the salt load is evaluated in the laboratory.

The wind speed and direction system uses an NRL developed sensor (Fig. 7 & 8) that has proven very reliable in the field (Von Wald, 1976). The electronic unit was designed for either independent operation or to be part of an externally controlled data acquisition system. The wind speed section has a propeller turn counter which operates over a timed interval. A built-in analog-to-digital (A/D) converter outputs 1 knot as 10 mV. The wind direction is sensed from a potentiometer which is referenced at zero volts toward the bow of the ship, reading to +1.800 V clockwise or to -1.800 V counterclockwise around to the ship's stern (giving 1° = 10 mV). Putting the singularity point aft reduces the probability of it interfering with a smooth data presentation, but does not eliminate the 360° (3.600 V) step at the stern. The circuit diagram is presented in Appendix II, along with a description of its operation. The analog output signals are converted to binary coded decimal (BCD) by DVM's (Weston Model 2472), which display and give a multiplexable BCD output. At least one meter must have a floating input or an isolated BCD output for referencing the wind direction signal.

The ship's speed and direction data were entered by thumbwheels, with appropriate changes made by the officers on watch. (The captain and the ship's officers on the CALLAGHAN were very helpful to this project in every respect).

The system operated continuously during its deployment with minimal down time, and about 1000 samples were collected for laboratory analysis. The radon counts and other data were printed out on paper tape. Data must be transferred from paper tape to the NRL computer by hand, pending development of a means for transferring the 4-bit data characters from the data bus to magnetic tape, in a format that is compatible with NRL's computing equipment. The Appendices which follow, detail the operational system removed from the ship in June of 1980. The technical descriptions are intended for use as a guide in understanding the circuit diagrams. Since the current configurations evolved from a series of improvements, some circuit functions might be accomplished with a simpler overall design. However, others such as the Mux Controller, should not be changed unless due consideration is given to the resultant states of the circuit for each up and down transition of the various clocking pulses. The Appendices provide an understanding of the major design ideas, as well as assist in troubleshooting the system.

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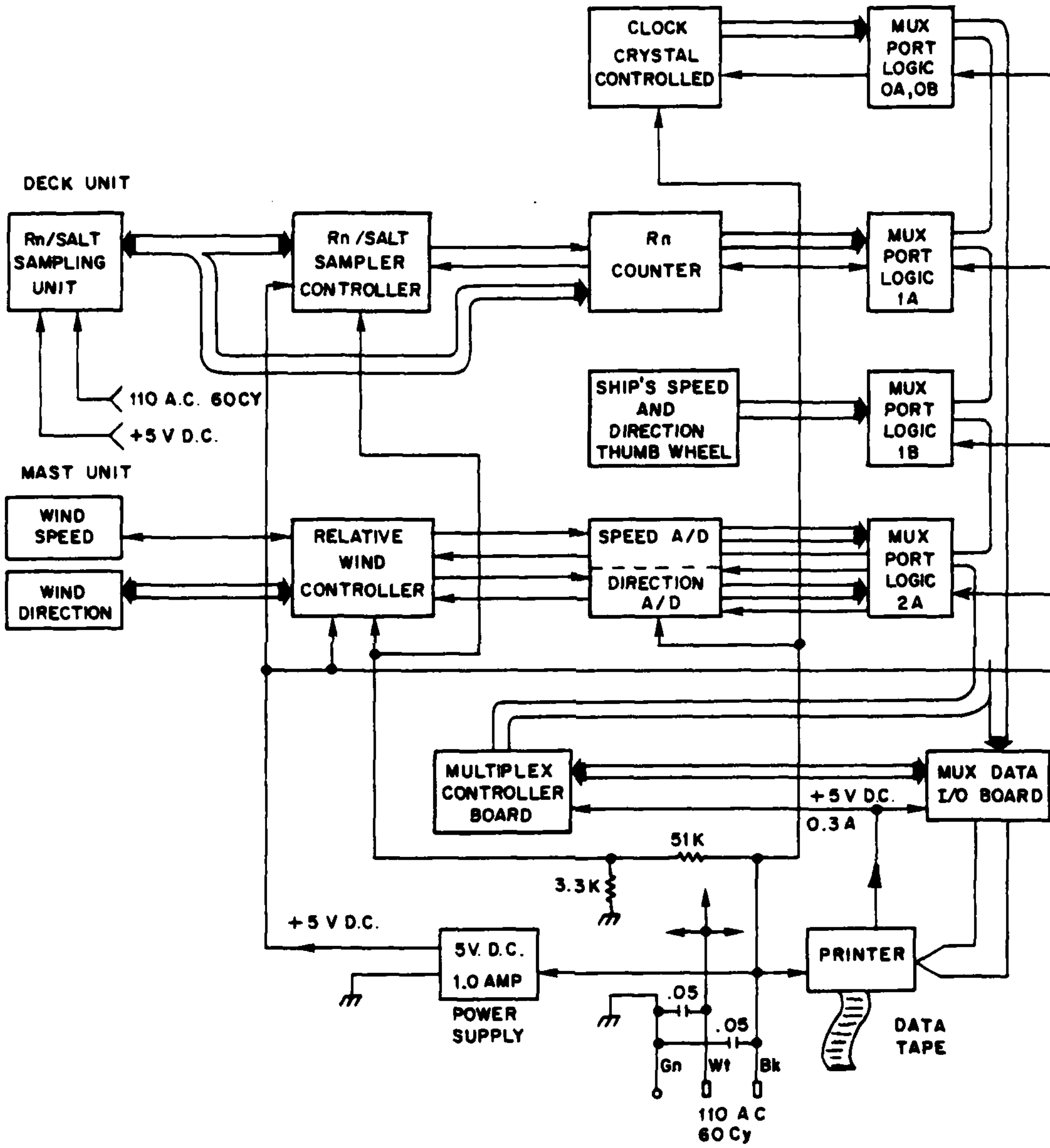

Figure 1: Block diagram of the sensing and data recording system, showing distribution of 5V D.C., 110V, A.C. power, and 60 Hz A.C. timing signals. The sensors are at the left and data moves from left to right toward the Mux system. Then, under control of the Mux Controller Board, data is transmitted from the Mux Port Logic boards, down the bus, through the Mux Data I/O Board to the printer.

Clock Lines	22	3654	Day of year and end of count time for next Rn sample
	FF	F123	
ARCAS	.00	1550	1st line, Port #1: 9th Rn count 9½ min. after previous one
"	.00	2000	
"	.00	2360	etc.
"	.00	2775	
"	.00	3275	
"	.00	3850	1st line, Port #1: 4th Rn count 10 more min. later
"	.00	4540	1st line, Port #1: 3rd Rn count 10 more min. later
ARCAS	.00	5350	1st line, Port #1: 2nd Rn count 10 more min. later
Wind	03	-7045	1st line, Port #2: Wind speed 37 kt., direction 45° counter clockwise from bow reference
Ship Nav.	.01	9268	2nd line, Port #1: Ship speed 15 kt., heading 268°
ARCAS	.00	+6300	1st line, Port #1: 1st radon counts = 630.0 cpm, printed at time shown
Clock Lines	21	0654	2nd line, Port #0: time 21 hr., 6 min., 54 sec.
	FF	F123	1st line, Port #0: day of the year #123

These decimal points are a BCD code. Read from left to right, tell port # supplying printed data

These three decimal points are part of the data.

This decimal point indicates a manual print (i.e. print requested by a button pusher).

Figure 2: Representative print-out of data for samples taken every 90 minutes, showing arrangement of data and location of flags. Note that for ARCAS the "+" sign is used as a flag for the first count of a sample, while for relative wind direction the sign shows which way the wind direction is measured from the bow, ± up to 180° with "+" indicating a clockwise angle and "-" indicating a counterclockwise angle.

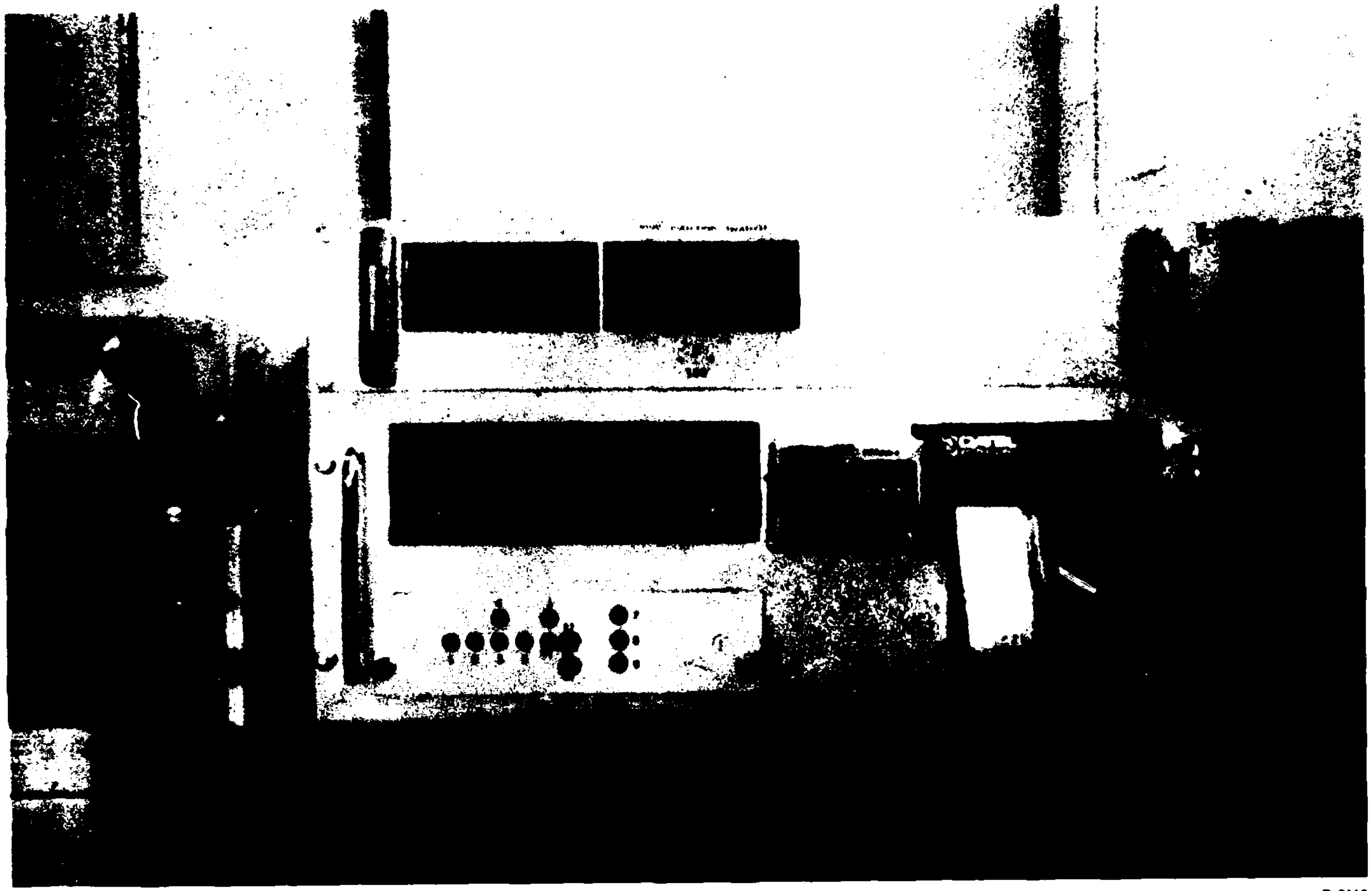

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Figure 3: Indoor unit mounted on a cabinet top in the rear of the bridge of the CALLAGHAN. On top are wind speed and direction displays, below is the day/clock display, below it is the ARCAS control panel, at center are ship's speed and heading thumbwheels, and at far right is the printer.

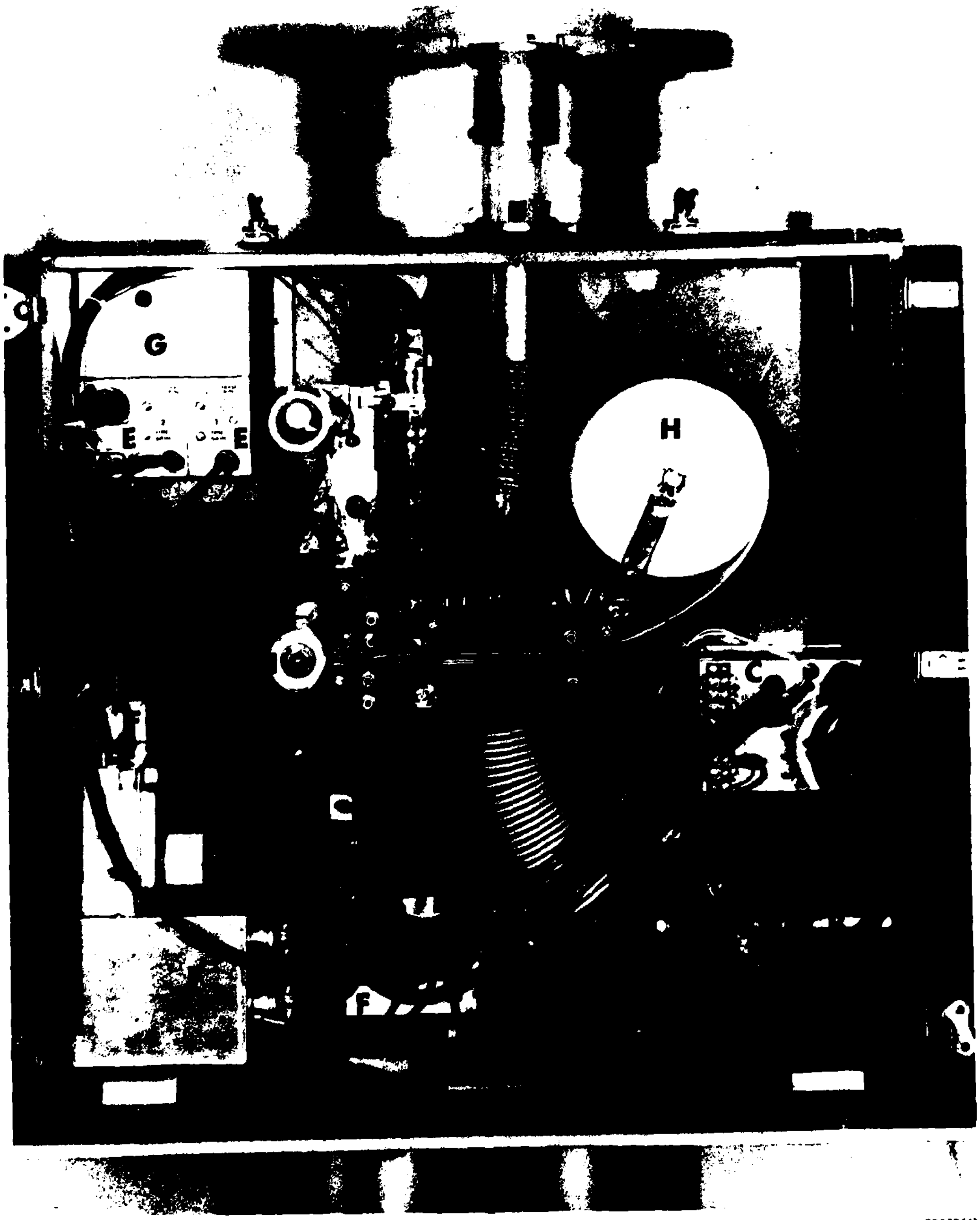

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Figure 4: ARCAS deck unit showing paper-tape transport mechanism (A), aspirating motor (B), motor controllers (C), radiation counting photomultiplier (PM) tubes (D), pulse amplifier transmitter units (E), high and low voltage power supplies (F), calibration counter (G), papertape supply roll (H), and take up roll (I).

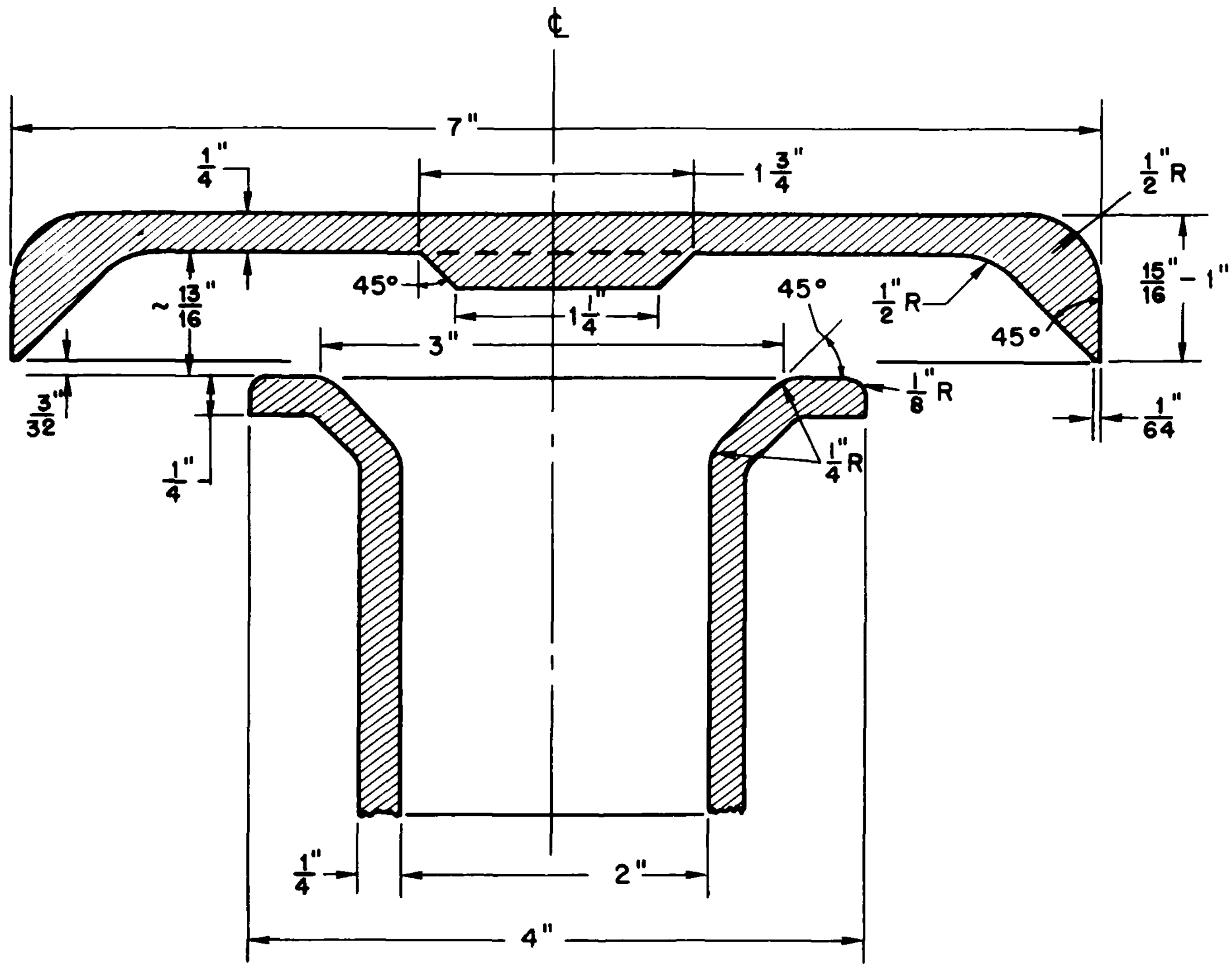

Figure 5: Omnidirectional inlet and rain shield for ARCAS.

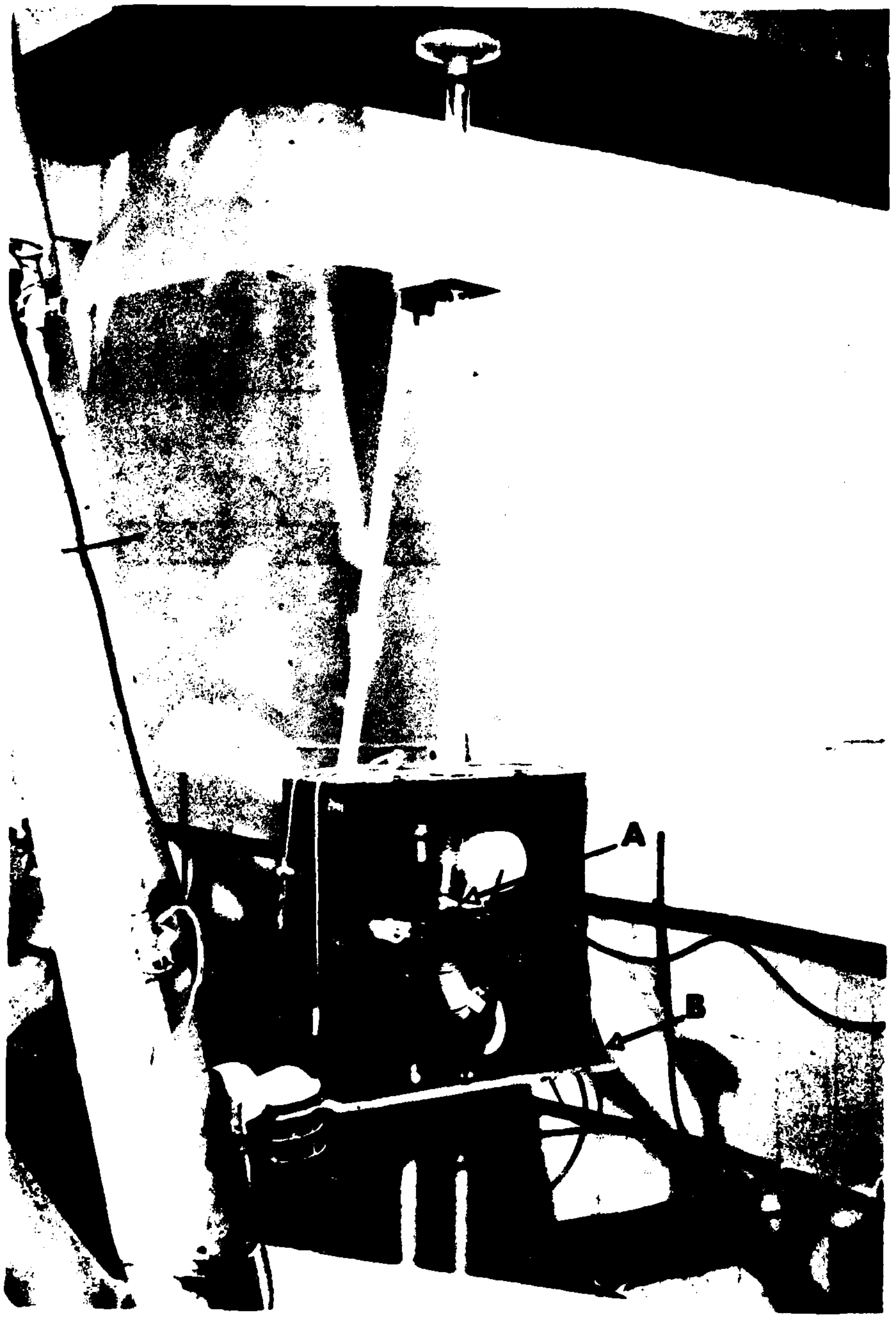

Figure 6: ARCAS mounted on the flying bridge of GTS CALLAGHAN. The heating tape (A) is visible on the air inlet tube betwoen the upper PM tube and the filter paper feed roll. The edge of the exhaust air deflector is visible at (B).

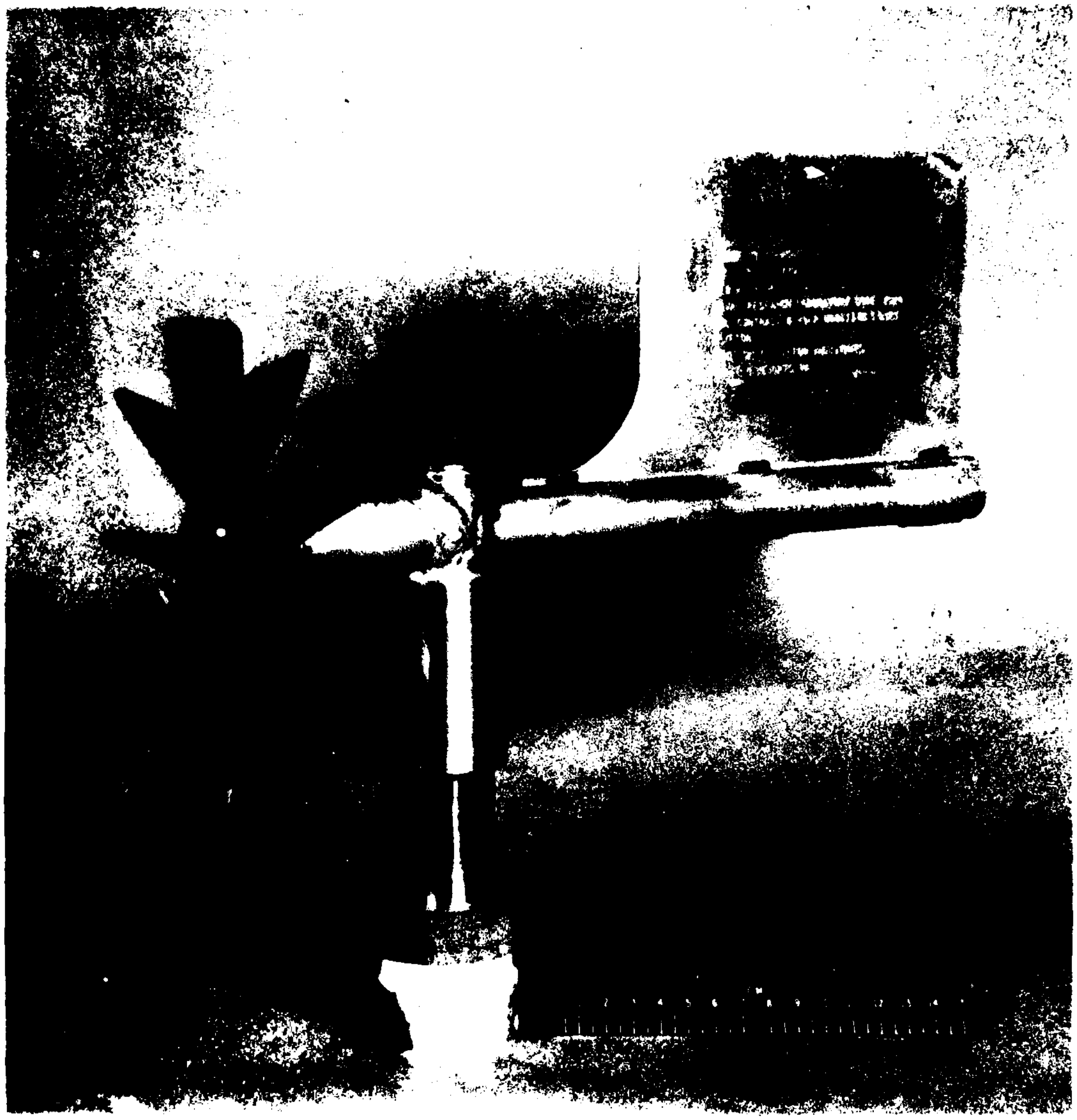

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Figure 7: Wind speed and direction sensor, previously designed at NRL. (See Von Wald, 1976).

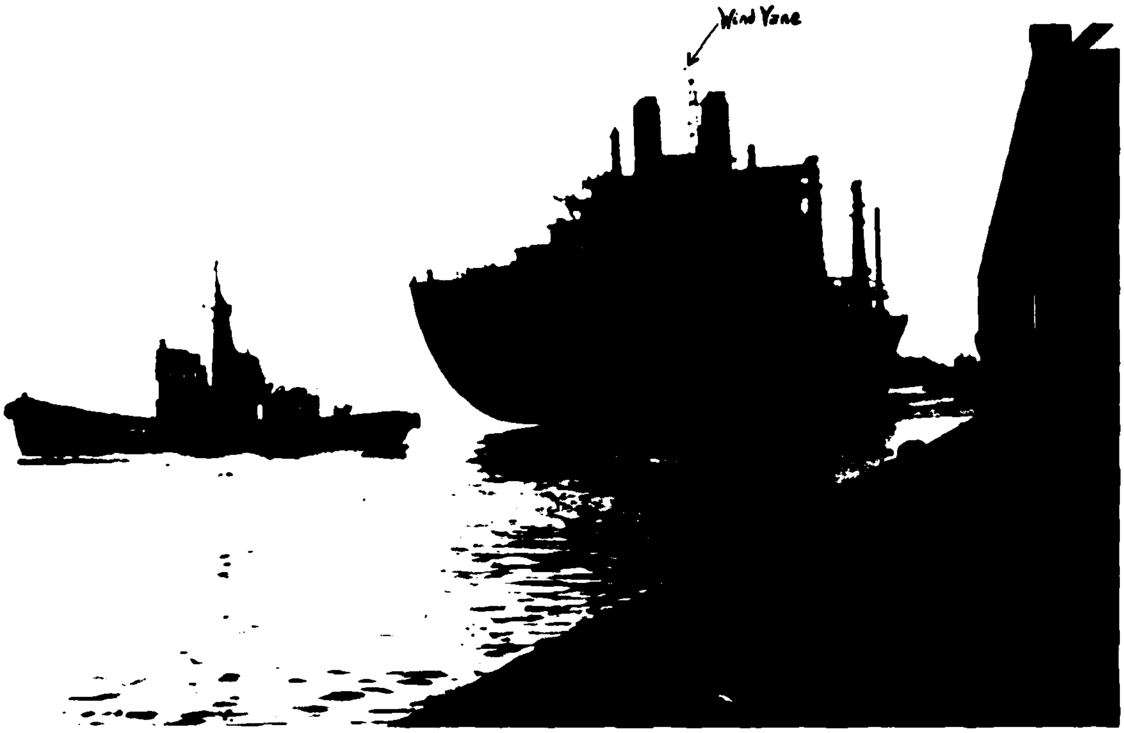


Figure 8: Approximate location of the wind sensor 40 m above sea level.

APPENDIX I: Multiplexer Boards

The multiplexer contains two boards on a common bus, which can accommodate future system expansion. In the configuration shown, the multiplexer is tasked to steer 4-bit BCD data, to a printer, and control the printer.

The two boards are the Mux Controller, which both coordinates data presentation and controls the printer; and the Mux I/O board, which reverts the data "true" polarity from low to high, stores the data to be printed in a set of latches, and includes logic for a manual print request button. The numbers and letters encircled on the diagrams are the pin designations on the plug-in boards and are also used as line designations for the multiplex system.

Controller Board

The two Mux Controller board logic functions may be separated on the circuit diagram by an imaginary line running from pin 20 on the left to pin I on the right. Above that line is the control logic which puts each 4-bit character on the data bus in its proper turn. This is done by stepping through the characters. One scan of the data normally encompasses 128 characters, which are divided up among 8 ports, with 2 lines (each of 8 characters) per port. The 307 KHz oscillator (UI-A, B, C) steps the binary counter (U2) through its 16 counts which are encoded at pins J, K, L, M. These lines communicate with all units which must keep track of which character is on the bus, including the Mux I/O Board. The print controller section of the board is set up to print a line after each string of 8 characters, i.e., when a binary 7 appears on lines NI, N2, N4. After U-2 puts 16 data characters on the bus (for a port) a signal is sent via U5-B to U3 (the port counter), which will put the code of the next port on lines 9, 10, 11, 12 and step the decoder (U4) to the next port. The decoder's output appears on only one of the 8 lines P_0-P_7 at a time. One line of this set is routed to each of the 8 ports as an exclusive "port select" line. When U4 "selects" Q9, the current scan is terminated and the Done line, pin 22, goes high.

The data lines and some Mux controlling lines form a 14-wire bus which communicates between the Multiplex System and each data input device. Each of the 8 input ports has a shielded female 14-pin plug connected to the bus. The connections are as follows.

Plug Pin #	Line		Mux System Function
1	J	N1-B	
2	K	N2-B	Character Address Code Lines (Pos. True)
3	L	N4-B	
4	M	N8-B	
5	N	D1	
6	P	D2	Data Transmission Lines (Neg. True)
7	R	D3	
8	S	D4	
9	1-8		Select Exclusive Lines, one per port (Neg. True)
10	X	G/P/H	Combination GO/PRINT/HOLD line
11	Y	ACC PRNT	Accessory Print Latch Line
12	22	DONE	Data Recording Mode Indicator Line
13	B	LPR	Line Print Returned
14	D	Freeze	(Not used in Mk-II)
Shield	A		Sig. & Chassis ground

Lines J, K, L, M coordinate the multiplexers and demultiplexers. Lines N, P, R, S carry the data with inverted polarity. Lines 1-8 are the exclusive select lines, which are used to turn ON the port through which data is to be accepted. Line X is a combination GO-PRINT-HOLD line, and pulling it low will start a scan at the next positive-going clock pulse, as seen on the timing diagram. Holding G/P/H low when '7' appears on the character address code lines will cause the previously transmitted line of data to be printed. Keeping it low during the time that lines J, K, L, M all drop from high to low will hold the Mux at that port for 2 more lines of data. If G/P/H is allowed to go high when LPR goes low the second time, the port counter (U3) will advance to the next port at that time. With the HOLD feature and the timing signals available from lines J, K, L, M, B and 22, an expander or an instrument which transmits a spectrum may be fed into any port. (It should be noted that if the data is to be latched into another memory (rather than a printer) the print signal (E) and LPR (B) may be used to do this if the print command is given. However, the BUSY line (C) must be cycled for proper operation after a PRINT command. For this, E might be connected directly to C in the absence of any external unit which returns a busy signal.) The ACCESSORY PRINT (line Y) sets a latch which controls the printout format. Two lines of data are printed for each of the ports selected by switch S2, i.e., 2, 4, or all 8. Line Y may also be monitored for logic content if necessary. Once set low it stays low for the whole scan, and unlike line 22 (DONE), it only goes low for selected scans. The DONE line (22) goes low for all scans and returns high when the scan is done. The LPR line (B) is a handshake and timing line so the transmitter can turn off the G/P/H line and prevent an inadvertent HOLD. The FREEZE line is reserved for future expansion.

On the lower section of the diagram there is circuitry to control printing and formating. The print cycle shown on the timing diagram is initiated by a low voltage on U6-12. It depends on U8-(2) being low when U5-(12) is low (i.e., a binary 7 on N1, N2, N4). This

can occur due to G/P/H being held low at that time, or by a command from the format section making the output at U1-(12) go low. The ACCESSORY PRINT latch being low can cause a data print, as could S1 being in the 2L position. (Normally it is set at 0L.) The ports for which two lines of data are automatically printed due to S1 or ACC PRINT are determined by S2, with 2P giving the first 2 ports, 4F for first 4 ports, 8P for all 8. Regardless of the condition of ACC PRINT, S1, or S2, a low signal at G/P/H at the proper time will cause a print cycle to occur.

The print cycle starts with U6-(12) going low causing U6-(9) to go low at the next clockrise. U6-(8) goes high to open the clock gate at U7-A, stopping further character advance, while U6-(9) causes U8-(8) and then U9-(2) to go low. U9-(6) will then go high on the next clock-rise, putting out a PRINT command. Due to the state of latch U9-B, LPR goes low at this time.

The system then waits for the BUSY line to be returned high at U9-(12) by the printer, an indication that it has secured the data in its own latch and is in the process of printing it. The next rising clock pulse at U9-B sets U9-(9) high and U9-(8) low. At this point LPR is returned high, and U8-(8) goes high. On the following clock pulse, U9-(6) will be returned low, turning off the print command. When the printer is finished, BUSY goes low, putting U8-(6) low, which immediately sets U6-B. On the next rising clock pulse U9-B is returned to its original state while the character counter will advance to the next port. Connecting U8-(4) to U9-(5) instead of a U9-(12), will allow the character counter to start advancing after the first clockrise following the busy return, accumulating a new line of data in memory while the printer or other memory devices are busy. A new PRINT command cannot be given until 2 clock cycles after BUSY goes low.

I/O BOARD

The Mux I/O Board latches the data and presents it to the printer over a 36-lead ribbon wire. Since the data is transmitted ground true, U10-A, B, C, D convert it to high true. The first character transmitted (bits 32-29) is stored at U1 and carries $\pm$ sign and decimal point information for the printer. The second character, stored at U2, is for future expansion. U3-U8 hold the six characters which will be printed with U8 being the least significant and last character transmitted. The character code N1-N4 is decoded by U9. The LATCH SIGNAL, a low at U9-(11), turns the decoder "On" by putting its output values in the range of 0-7. The code on N1-N4 will cause one output line to go high, allowing one appropriate latch to be transparent. When the LATCH line goes high the output of U-9 assumes a value greater than 7. Then, no latch is transparent, and the latest data character is locked into the previously transparent latch. On the next clock cycle, the next latch will accept the next data character appearing on the bus. (Note that U2 and U3 on the Mux Control board have a parallel load feature. With the proper circuitry and interlocks an external device might be employed to control ports and characters putting data on the bus.)

Bits 33-35 carry the number of whichever port is being printed, while bit 36 flags the condition of the manual print latch. That latch allows an observer to cause a scan and have all the valid data printed. "Valid" data refers to a complete data set, such as a complete radon count. The port logic interface boards are wired to put zeros on the line for incomplete data.

Port Logic

Each port logic board must have a set of multiplexers capable of transmitting negative true data, and its logic is tailored to interface each particular data supplying unit to the multiplex system.

The Clock Mux Transmitter is a passive interface which presents time data for every scan. The unit requesting the scan orders a print, either through timing of the G/P/H line or by latching ACC PRINT low. A low on ACC PRINT is used to inhibit data changes in the clock's output latches during those scans when prints are requested by the ACC PRINT line. (Alternately, DONE could be used for the same purpose.) Note that SELECT (9) comes from line P_O on the control board, since the clock is plugged into the "zeroth" data port in this system. Two lines of clock data are printed, line A has the day of the year and line B has hr., min., sec. The data is handled by U1-U4 which are 16-bit, data-inverting multiplexers. Since the 74LS150 is not a tri-state unit, isolating diodes are used between them and the data bus. Also, the originally positive true data is inverted and sent as negative (or low) true.

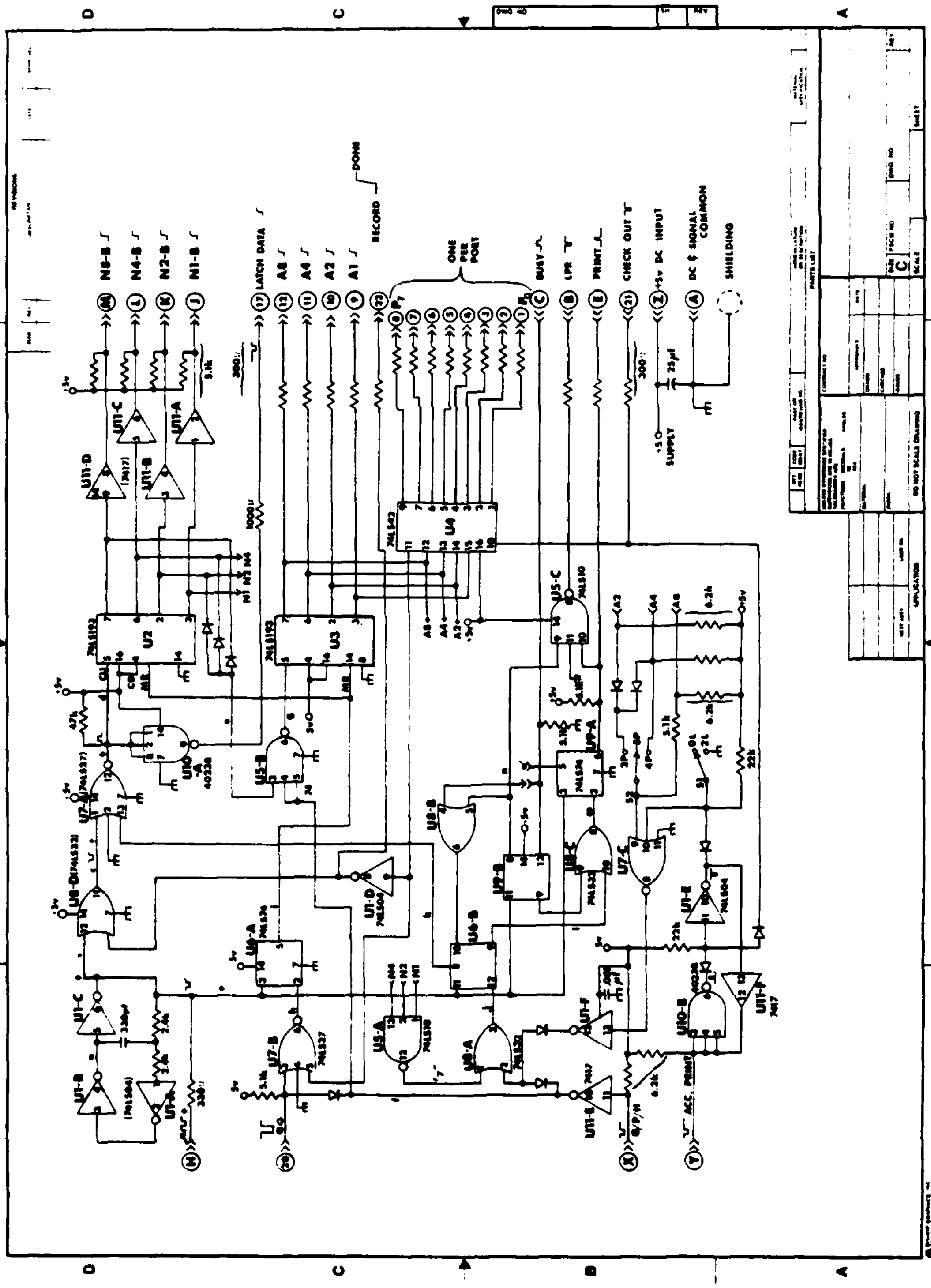
The ARCAS data is entered at port 1, line A and its interface is the most complex of all. An explanation is reserved for Appendix III, since a glance at the simpler interfaces first might be more instructive.

The six BCD output thumbwheels (three characters for ship's speed and three for heading), feed their data in as the second line (line B) of port 1. Looking at the circuit diagram one can see that SELECT (line 9) (coming from P1 for this port) has to be low while N8-B is high (indicating characters 8-15), for U5-B to enable the multiplexing chips U1-U4 to put their data on the line. The 74LS251 tri-state chips had to be used. This is due to the thumbwheels presenting their data as negative true and the particular effect the enable line has on the true and inverted outputs of the non-tri-state 74LS151. They can only be used to invert and transmit positive true data without problems. (The 74LS251 can be used either way, however).

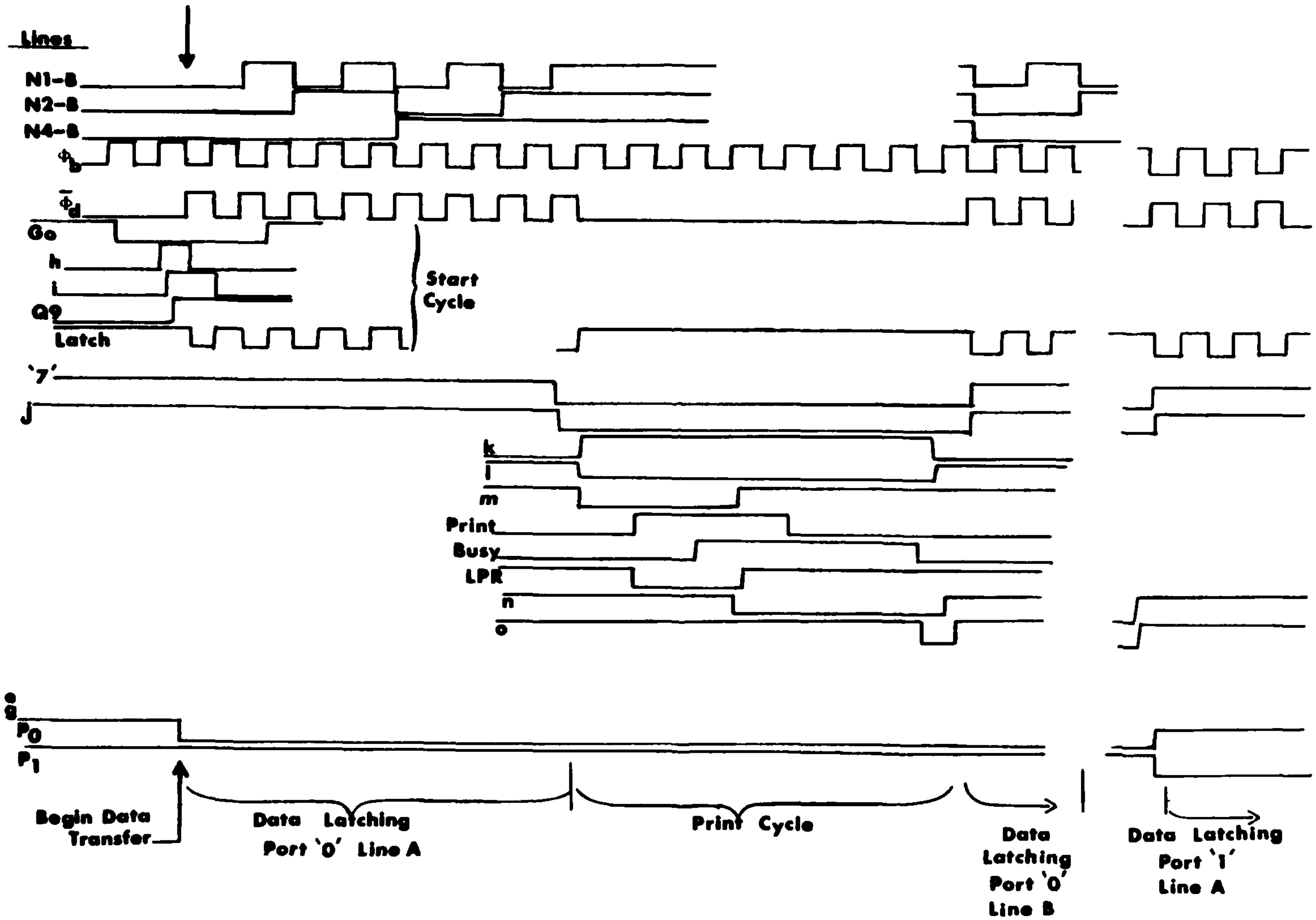
Wind speed and direction data is fed to the bus through port 2 line A by 4-74LS150 16 bit multiplex chips. The port logic is shown in the next diagram. This unit was built to feed data when the ACC PRINT line was triggered, and with expansion capability to count scans and supply data on the third and/or sixth scan after ACC PRINT as chosen by S1, S2, S3. With S1-S3 ON no data would be printed, while with S4 ON data would be printed on every scan. (Implementation of this capability has not yet been necessary.) Note that

the DONE line (which goes low during a scan) is also fed to the wind speed data displays and registers (a pair of DVM's). This keeps the registers from updating during a scan. The G/P/H line is only used to command a print cycle since the scans in this system were only triggered at ACC PRINT by ARCAS when radon data was ready. The select line (P2 in this case) is used to only show data (to the bus) and allow printing when this port is on. SHOW DATA goes to the enable pins of the 74LS150's, and since they are 16 bit chips, N1, 2, 4, 8-B are decoded directly by the chips and no further logic is necessary to manage the 2 lines of data. Scan counting is straightforward; at the end of a scan (when DONE goes high) the counter U1 is incremented. When the appropriate output line goes high, one of the gates of U3-A will go high if its grounding switch is open. Then, U3-(12) goes low, and with SEL and N8-B both low U3-(6) goes high allowing U3-C to function pulling the G/P/H line low. Note that LPR is low for about two or three clock pulses after a print command is given, i.e., until the return busy signal is clocked in during a print cycle, this releases the latch holding G/P/H low.

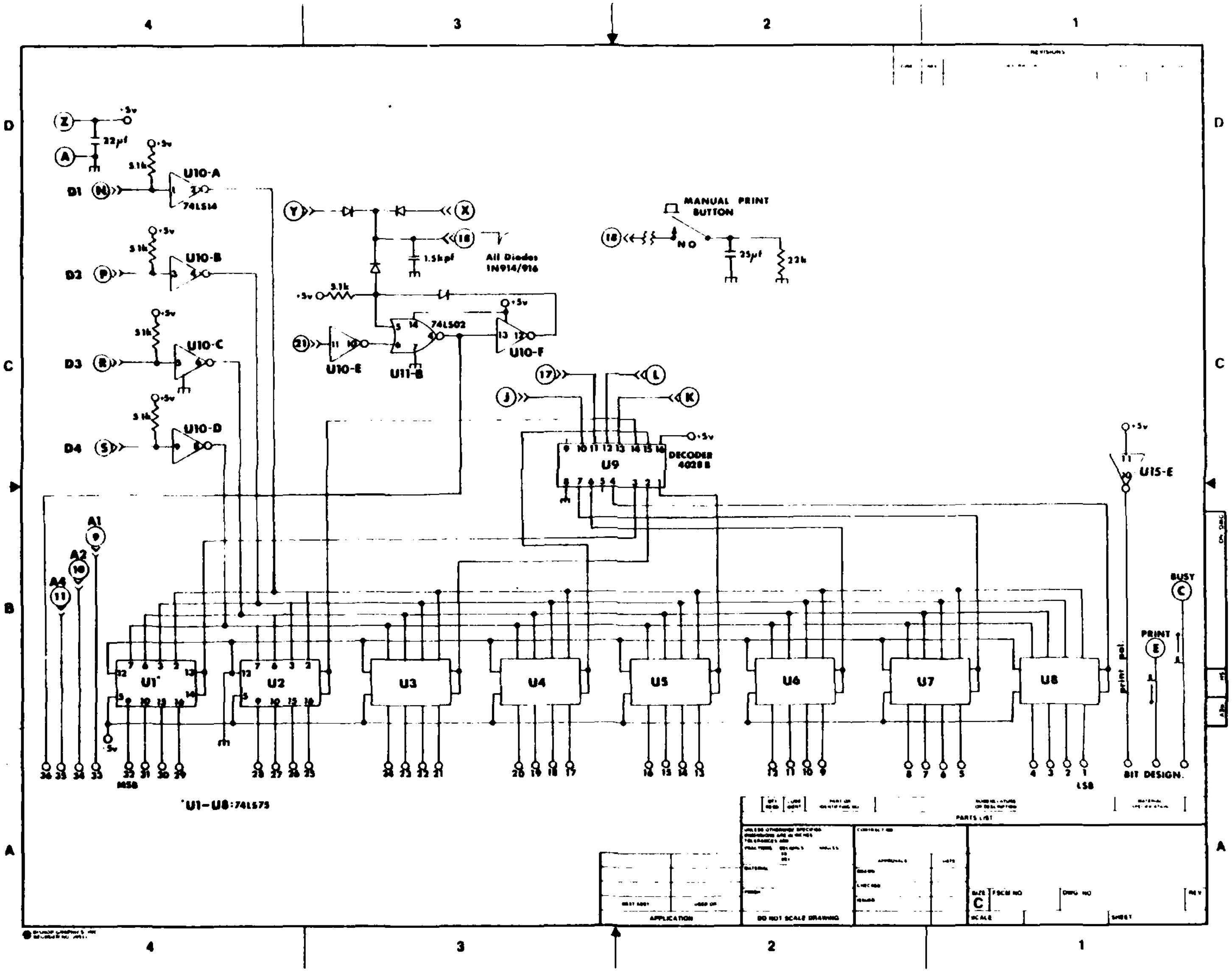
As shown, the Mux Controller has proven to be a good unit to control the polling of multiple digital voltmeters, having BCD outputs. A data bus accommodating any number of bits can be used. A control function called Freeze is intended for insertion at U7-2 on the Controller Board. It would allow clocking while inhibiting character advance. The 307 kc oscillator may then be counted down to obtain various baud rates, while holding one character on the data bus for any necessary duration.



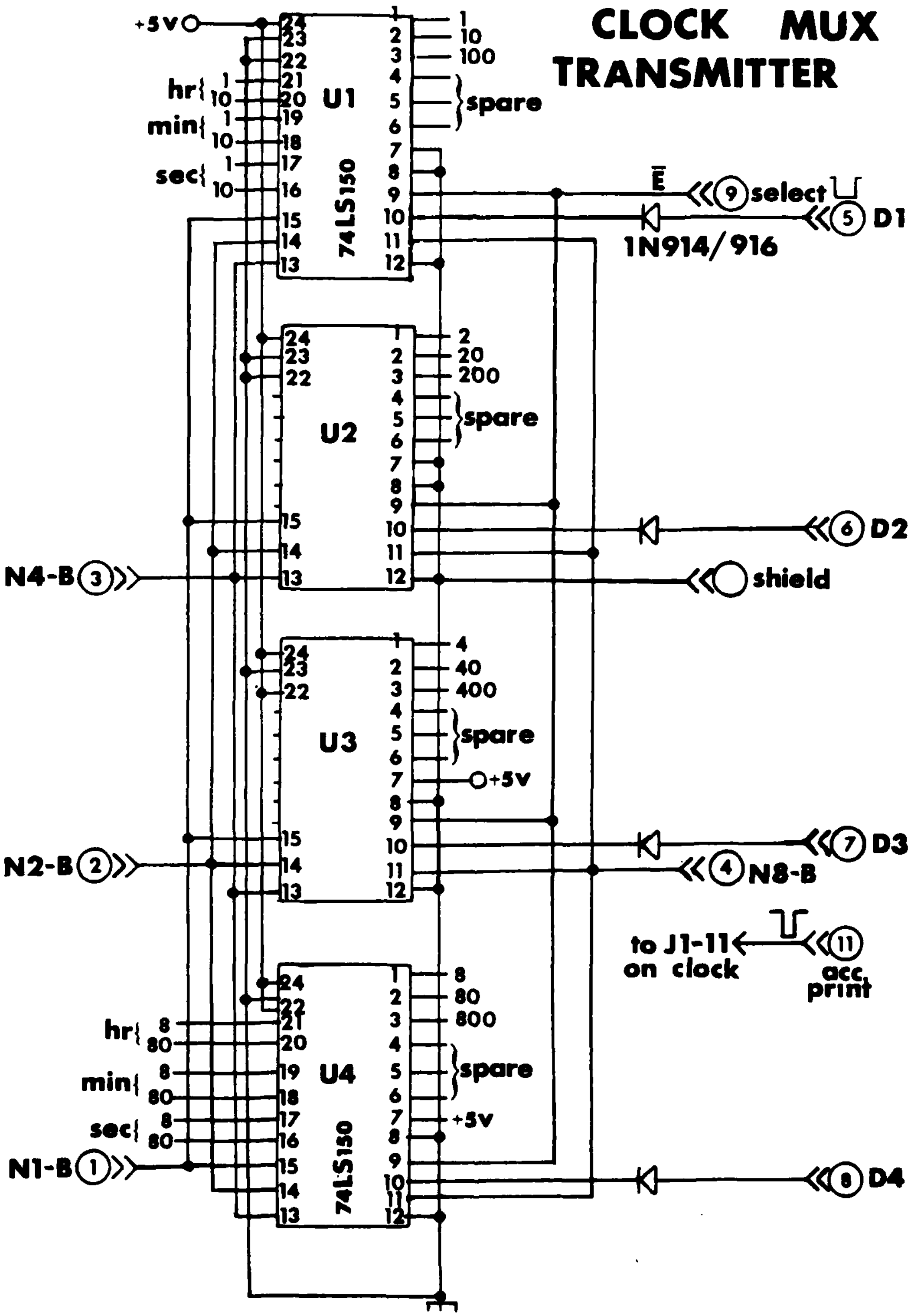
Multiplex Controller Board



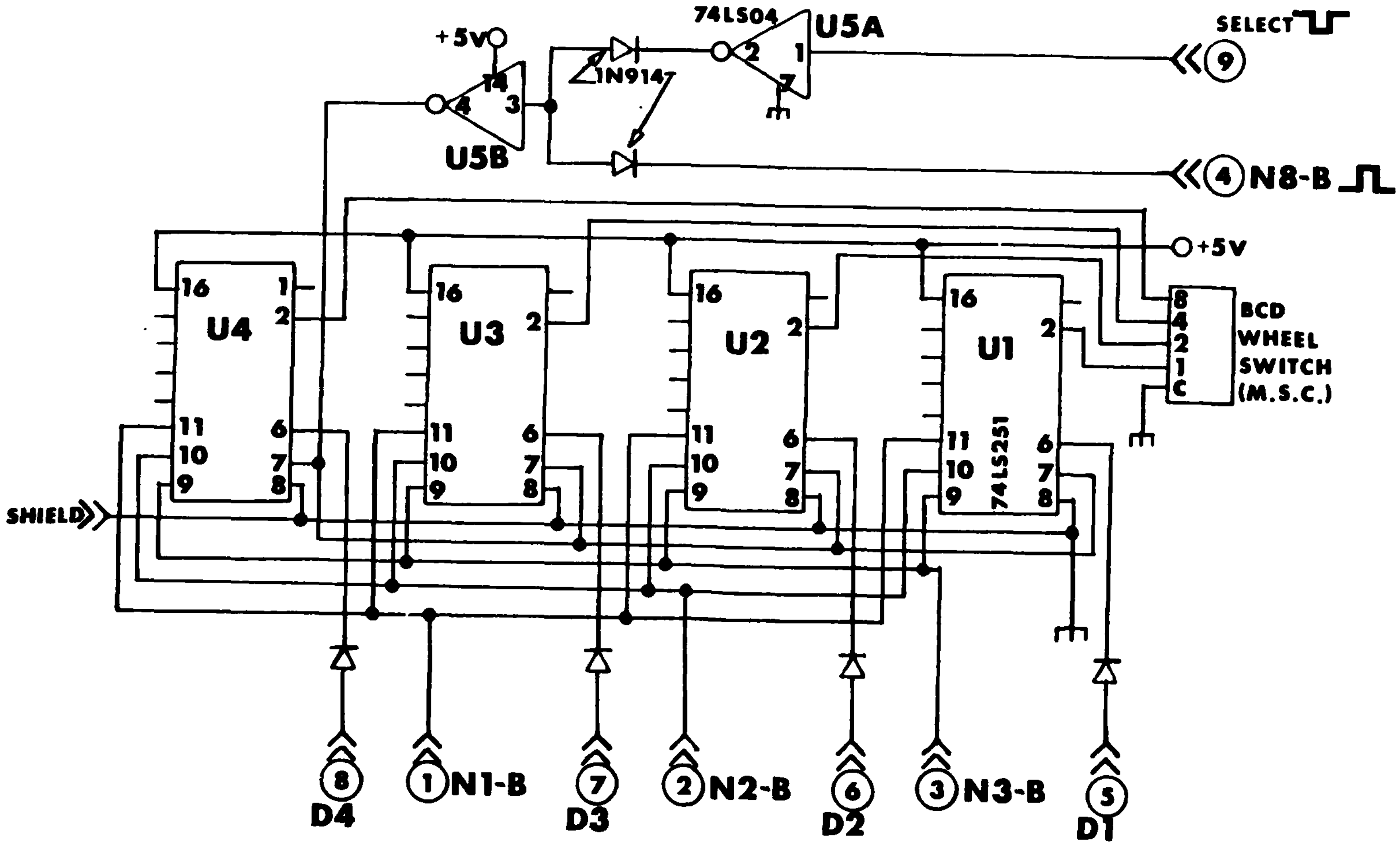
Controller Timing Diagram



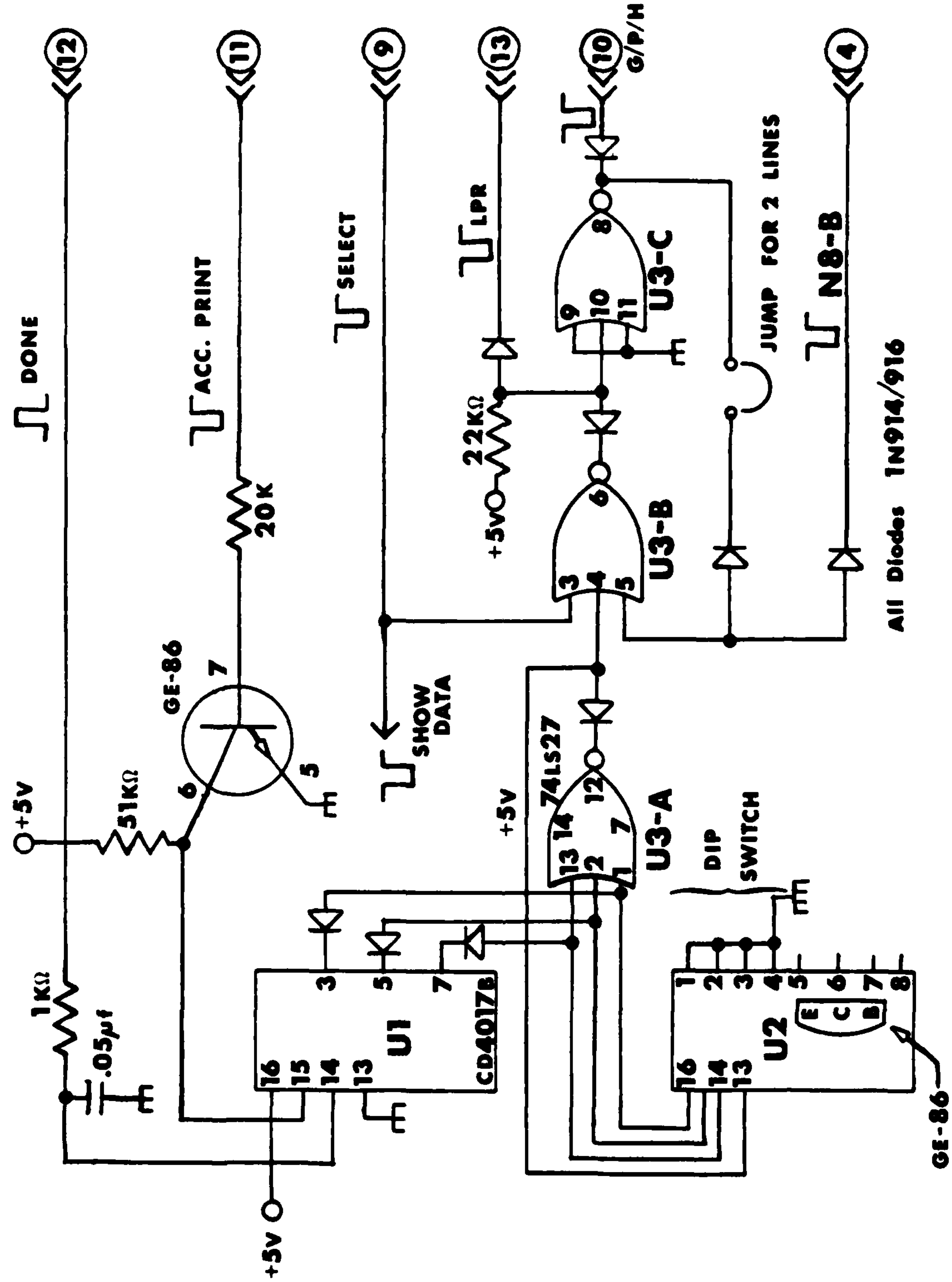
Multiplex In and Out Board



Multiplex Data Transmitter for Clock or Wind Vane



Multiplex Data Transmitter and Port Logic for Thumbwheels



Port Logic for Wind Vane

Appendix II: Wind Speed and Direction

To understand this circuit, we will start with the sensors. The propeller (Figure 7) has been calibrated at 30 magnetic reed switch closures per min. in a 20 knot wind, and is linear over the range of interest. The direction indication is obtained from a low-torque precision potentiometer with a 7-degree dead band. Magnetic couplings are also used in the direction section. The direction unit is installed with the midpoint of the pot toward the bow and the dead band to the rear, providing ± 1.800 V readings from the bow when a suitable reference voltage is provided.

The circuit counts reed switch closures for 2/3 min. or 2/3 of 10 min. This makes the total count equal either knots or tenths of knots, respectively. The circuit incorporates a built-in D-A converter and has provisions for internal electronic calibration. It also provides a supply voltage for the analog direction potentiometer of + 3.600 VDC, a reference voltage of + 1.800 VDC, and handshake signals for the multiplex port logic board and DVM's used to record and display the wind data.

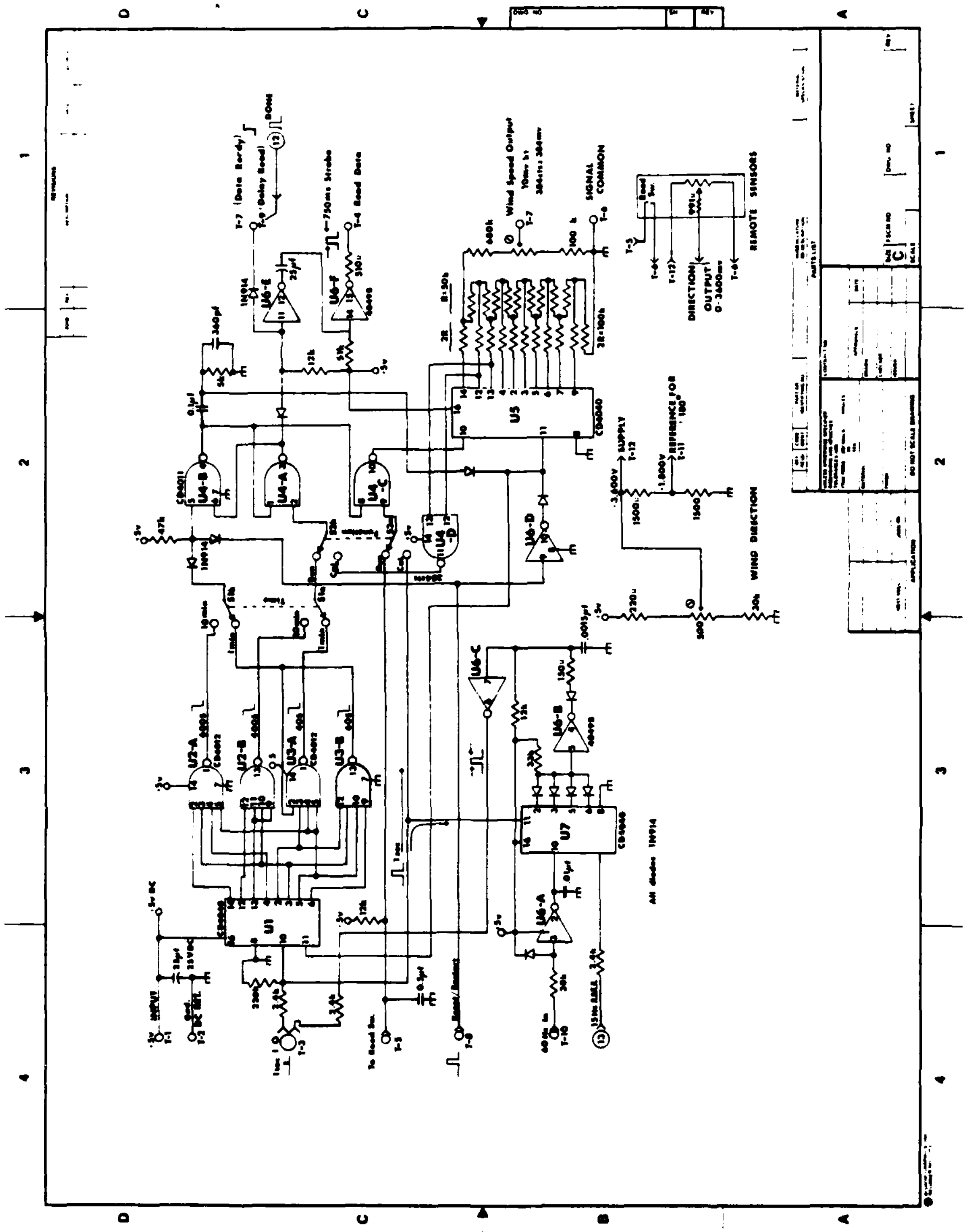
The time base is taken from the 60 Hz line. The signal is fed into the unit through the (51K/3.3K) resistor network shown in Figure 1 and the 30 K resistor between (T-10) and U6-(3). U6-A is a buffer which squares off the pulse and helps filter out noise spikes. The 60-Hz square wave is fed to U7 where it is counted (+o 60) for a one-second signal. The "60" is decoded at U7 outputs by the diodes which allow the input of U6-B to go high. At that time, U6-(4) pulls low causing U6-(7) to go low, making U6-(6) go high. This rising edge is fed into the propeller turn counter timing circuit at U1-(10). The circuit counts to 60 (or 600) seconds before resettings giving shut off pulses at 40 (or 400) seconds. These intervals are decoded by the different sections of U2 and U3. The 1-second pulse is also immediately returned to U7-(11), a reset pin which causes U7 to go to zero and U6-(4) to go high. However, since the diode isolates U6-(7) from U6-(4) when the latter is high, the low voltage on U6-(7) is maintained by the 0.0015 μf capacitor, which gets charged through the 12 K ohm resistor. This results in a 6 μs long pulse every second. Note that if a short duration external pulse is fed at (T-3), U7 resets, and the 1 second pulses will be synchronized with it. If a long pulse is used, time starts accumulating from its falling edge.

The propeller count accumulation is repetitive. A one-min. cycle starts at the 60 second reset point, by setting the latch made up of U4-B and A, causing a high signal on (T-9) to go low. The high signal at U4-(4) becomes a pulse, (due to the 0.1 μf capacitor) which resets U5, the D-A converter, and U1, the seconds counter. Propeller switch closures are sensed at (T-5) (by ungrounding). The rising pulse comes in through gate U4-C, whose inverted output falls and increments U5, the switch closure counter. D-A conversion is handled by the binary ladder resistor network (R and 2R). At 40 seconds, the U4-A, B latch is reset, turning off the count gate at U4-(8). At that time DATA READY (T-9) goes high, and READ! (T-4) pulses high for 750 ms. These signals indicate a valid count and reading at (T-7). Note that the

pulse at (T-4) can be delayed by an external device which holds (T-9) low. DONE from the Mux Controller is attached there, preventing (T-4) from triggering during a scan. In our system (T-4) was tied to a HOLD PIN on the "speed DVM", only allowing an update when (T-4) is high. By all this, DONE being low prevents the data presented to the Mux transmitter chips (by the DVM) from changing during a scan.

Switching S1 to 10 min provides for 400 seconds of counting, with a reset-restart occurring at 600 seconds. The output data is then read in tenths of knots instead of knots. U4-D is a calibration gate. With S1 set at 10 min, and S2 set at cal, the 1-sec pulses are run directly to U5. When U5 accumulates 384 counts the calibration gate decodes it and turns the latch off at U4-(2). At that point, R1 is adjusted so that 384 MV appear at (T-7). Note that in the 10 min. mode 384 Mv would equal 38.4 knots, while in the one min. mode it would equal 384 knots. Restoring S2 to run will put the wind speed sensor back into operation on a continuous basis. (T-8) is an external reset-restart line for synchronization. Time begins to accumulate when (T-8) is allowed to go high.

The Wind Direction section is much simpler. With the wind vane attached, R2 is set so that a reading of +3.600 V is obtained at (T-12), preferably by the same meter as used to display the directional data. The two 1500 ohm resistors are matched to provide a voltage at (T-11) which is exactly 1/2 that of (T-12). When in operation, an isolated BCD outputting DVM is used with its sensor attached to the Direction Output line returning from the vane, and its reference attached at (T-11). In this way, dead ahead reads 0 V (0°), clockwise angles to the stern read 0 to +1.80 V, and counterclockwise angles read 0 to -1.80 V. An adjustable R-C network is used at the input of the direction DVM to smooth out short term fluctuations.



Wind Speed and Direction Board

Appendix III: Automatic Radon Counter and Aerosol Sampler

The Automatic Radon Counter (ARC) was designed to collect radon daughter products on a filter paper, then advance the sample to counting tubes when collection is complete. A series of 10-min. counts are taken to evaluate daughter product activity and indirectly the radon concentration of the air. The overall working of the ARC unit is described in the references of Bressan and Larson for 1978 and 1979.

Since the used filter paper is rolled up, and collected particles were found to be well imbedded into the surface of the filter paper, sample spots can be evaluated for sea salt content after returning the used filter paper roll to the laboratory. To enable a more representative sampling of the total atmospheric salt loading, considerations were given to inlet design and placement as stated in the foregoing text. The improved unit in its new role was renamed Automatic Radon Counter and Aerosol Sampler (ARCAS).

Circuit diagrams are presented for the various electronic boards and features incorporated in the new design. A Control Board provides timing, sequencing and control, and LED display activation. A Data Board takes care of data pulse reception, counting, count timing, analog output provision, and output control, which consists of the ability to control a printer directly as well as a built in multiplex transmitter and logic interface section. The Motor Control Board in the deck unit receives CMOS signals and uses them to control the blower and tape advance motors via opto-isolators. It also has pushbuttons so the operator can remotely manually manipulate the Control Board electronics from the sampling station. The Front Panel Circuits provide a display for the state of the system and pushbuttons for local control. An Interface Diagram specifies control board interfacing, through the front panel circuits, with the Motor Control Board via an interconnecting cable. Finally, the Pulse Handling Board is also located in the deck unit, transmitting data back to the Data Board and providing a manually controlled counter for calibration checks of the detectors when using a beta source of known strength.

Deck Unit Boards

Pulse Transmission:

The Pulse Handling Board has two identical pulse handling circuits which take signals from the upper and lower PM tube end preamplifiers (we used Canberra Model 2007-P base mounted units) and combines the pulses with a NAND gate "adder" (U4-D). All pulses are transmitted by U6-B, an 8830 linedriver, down a pair of wires to an 8820 line receiver (U16) on the Data Board. U1-U3 are the combination counter/display chips used as a calibration counter. S1 turns the counter chips on, S2 allows counting by putting the pulses onto the clock lines. (The operator must manually time the period that S2 is closed. The reset button (B1) returns the counters to zero.

The pulse-handling sections have two stages of gain, one of which is variable from G = 0.14 to G = 475; the other is fixed at G = 24. The LM 111 compares the pulse height with a reference level set by the 5K ohm (Discriminator Level Adjustor) potentiometer. All pulses exceeding the discriminator setting will trigger the one-shot multivibrator (U5), giving a square pulse to the adder (U4-D), whose output is then transmitted via the data cable to be registered by the counters on the Data Board. It was necessary to shield these electronics from stray fields inside their box, and 3/64" aluminum was found adequate.

Motor Controllers:

The Motor Controller Box provides a housing for the Motor Control Board and a mount for the controlled 110V AC receptacles, the control cable socket, the remote control pushbuttons, and indicator LED. A motor control circuit consists of an opto-isolated, TTL-compatible input, two transistors and a 15-amp, 250-volt TRIAC. The commands to RUN or STOP come via cable from the Control Board. In the case of the paper tape advance motor, the increment of travel is indirectly measured by cam lobes on the paper tape feed roller. The lobes contact a microswitch, whose information is fed back to the Control Board via the connecting cable. The pushbuttons are also tied into these control lines. The Control Board responds to the information on the lines and gives the appropriate commands.

The pushbuttons can be used to stop the blower and initiate a paper tape advance (B2-stop/advance), and to restart the blower and reset the timers to the beginning of a cycle (B1-reset/restart).

(The buttons can also be used to put the controller into the 1-min. count mode, which it will automatically exit after 9 min., by the following sequence: Push B1 followed closely by B2, then release B1 and then B2.)

In the TRIAC circuit shown, TRIAC (Q1) would always be firing if circuit points Q2-E and C were simply connected. The bias applied to Q2-B by the 50K ohm resistor would accomplish this. But, Q3 is biased ON by the 220K resistor, and this keeps Q2 open and therefore Q1 open. When the opto-isolator LED is turned on, the opto-isolation transistor (Q4) conducts, which turns off Q3. This allows Q2 to conduct, which turns on Q1 enabling the motor to run. The GE 222's were chosen because they can run from the high pulsating DC fed directly to them by the diode (D1). The triggering of Q1 can be optimized by adjusting the value of capacitor C1. This circuit shows minimal voltage drop when on, and minimal leakage when OFF. It can also tolerate either side of the line grounded or a balanced AC line (when referenced to ground), and can be serviced (if necessary) in the field. However, generous heat dissipation is required for CR-1, the Blower TRIAC. Alternately, an opto-isolated relay (such as Teledyne 611-4) may be substituted for this circuit. However, these must be replaced as a unit if they malfunction. Shortcomings of other TRIAC control circuit designs have led us to these two alternatives.

The Indoor Unit

The Front Panel Circuit diagram shows the indicating LEDs, their drivers and the pushbuttons wired behind the front panel. The Control Interfacing and Connections diagram details the control connections between the Control Board (shown on the left) and the Motor Controller (shown on the right), via the front panel circuitry and the connecting cable. The data pulses are also transmitted directly to the Data Board via this cable.

An identifying list of the indicators and switches is as follows:

Lt. # (1) Amber = Blower Run Command (20 minute sample)
(2) Amber = Blower Run Memory (∿ 16 sec)
(3) Amber = Tape Go Command (∿ 22 sec)
(4) Green = Tape Return (∿ 16 sec)
(tape GO is being executed)
(5) Amber = Waiting (70 minutes for a 90 min. cycle)
(6) Green = 1 min. time indicator (on for 26 sec.). Upon going off a 500.0 µsec. pulse occurs to mark the min.
*(7) Red = 1 min count mode - Blinks simultaneously with #4 to indicate the 1 min. count mode. The 1 min. count mode is exited automatically after no more than 9 min.
*(8) Red = Remote Date Transmitting Circuit (in outdoor box) is inoperative, i.e., off, disconnected, or burnt out.
*(9) Red = ACR Indicator - The ARC controller is off.

*Red lights should not be on during normal operations of unit.

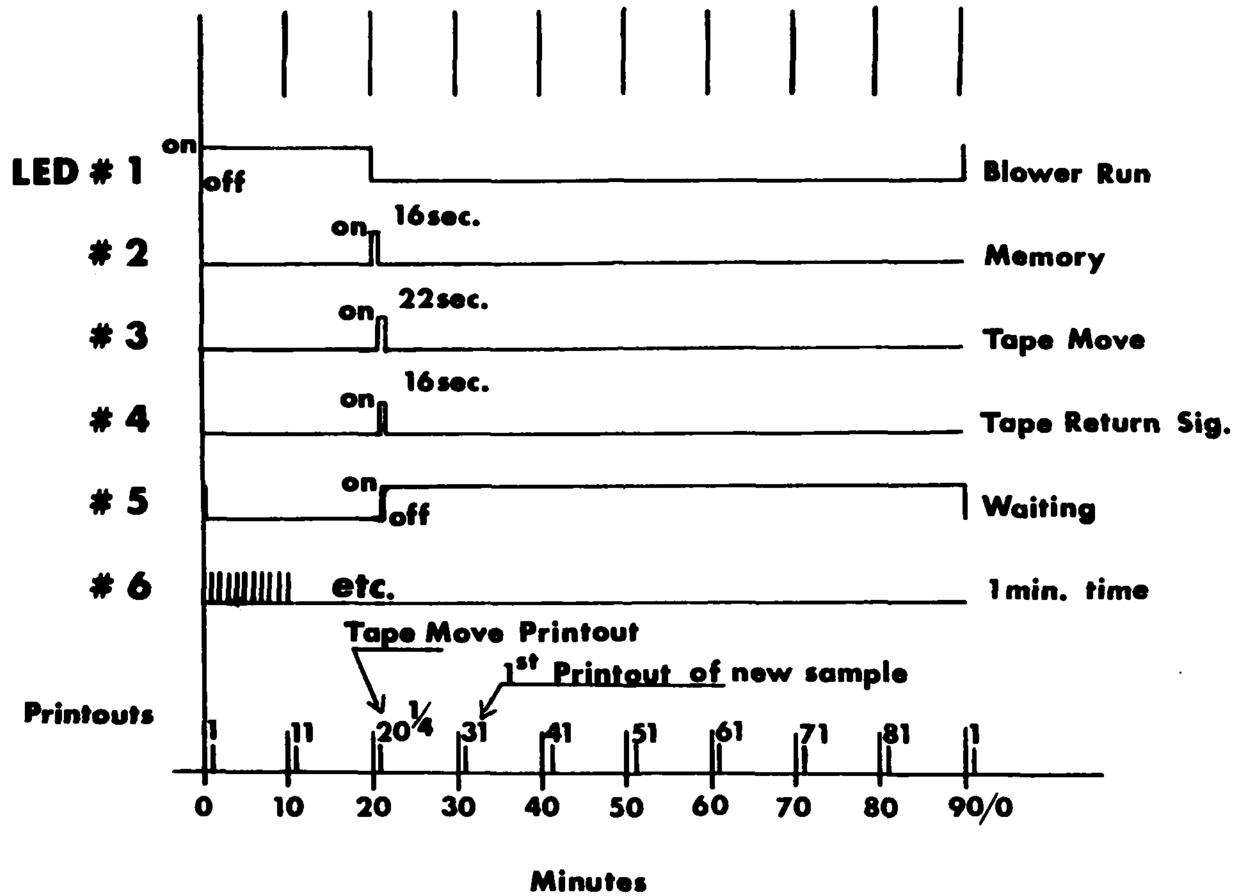
B2) Stops blower, and advances tape. To advance tape, hold in until tape return LED (#4) comes on, then release. The cycle will be concluded automatically.

B1) Starts the blower, resets the time cycle to the zeroth minute, and can be used to cause exiting from 1 min. count mode.

S1) 5V - DC ON/OFF switch.

Overall Timing

The diagram shows when the various LEDs would come on during a 90 min. sampling cycle. As will be seen, cycle lengths of 30, 60 or 90 min. are selectable (as well as 20 or 40 min. sampling durations) by DIP switches.



ARCAS LED Timing

Control Board

The sampling cycle is controlled by the various outputs of the minutes counters, U3 and U4. At the start, the minute counters are reset to zero by a boot strap pulser made up of U7-A and U6-C, and are subsequently incremented once a minute by a pulse from U6-B. The START signal also sets the Blower Run Latch (U11-A) to turn on the aspiration motor for sample collection, provided the interlocks originating at U6-D, U8-A, and U11-B allow it. The "Blower Run" command is transmitted by U5-E to the appropriate opto-isolated receiver on the Motor Controller Board. After counting 20(or 40)-minute pulses, the stop line (from S4) goes high, sending a pulse to reset U11-A and turn off the blower. When U11-A changes state, the rising voltage at U11-(2) clocks the Memory latch U11-B ON. (U11-B "remembers" that U11-A underwent a transition from ON to OFF.) This "unlocks" the gate at U7-(9). Sixteen seconds later the line coming into U7-(8) also goes low, and, provided the interlocks are off, a TAPE RUN signal is transmitted from U7-D. At this point the tape transport Feed Roller revolves, moving the paper and a microswitch cam. As that switch opens, it grounds the line at pin 12, turning off the Memory Latch at U11-B, but providing a substitute run command at U10-C. This returned ground also illuminates LED #4. Now the microswitch itself sustains the TAPE RUN command from U7-D until a cam lobe closes the microswitch, about 22 seconds later. The closure ungrounds pin 12 and allows the tape to stop moving. One can see that momentarily depressing B2 will cause U6-D to go high, resetting U11-A and stopping the blower if it were running. This instantaneous pulse would cause insignificant tape roller motion so that the microswitch would remain closed. However, holding B2 depressed would allow the tape drive motor to come up to speed, eventually moving the cam which would cause the microswitch to sustain the tape motion throughout a complete sample change cycle. It will be seen on the Data Board that the first minute pulse (at pin-D) after the tape moved will begin the first 10 min. count cycle for this sample. Therefore, the first 10 min. count is finished 11 min. after the blower stops collecting the sample. The minute counters keep counting minutes, and the radon counters keep accumulating and printing out 10 min. counts. At 90 min., a pulse comes through causing the Start/Reset line to go high, which triggers the boot strap pulser (U7-A and U6-C), causing a reset of the counters and a restart of the blower motor. The radon counters keep counting and printing the results until the tape moves, at which time they print, reset to zero, and await the next minute pulse, which signals the starting point for a new set of 10 min. counts on the new sample.

The controller board performs other functions besides sequencing the sampler. A panel return line is provided at pin-15 for B1 to restart the blower (via U9-B operating the boot strap pulser), since B2 can turn the blower off. The R-C networks at U5-C and U6-D, with the gate U7-B, decode the pushbutton sequence, previously described, that puts the unit into a 1-min. (vs. 10-min.) count/print mode. This is done by latching U8-A, which turns on the 1-min. gate at U9-A, the warning blinker gate U9-C, and resets the minute counters via U9-B. The one-min. mode is exited when B1 is momentarily closed and opened, or automatically after 9 min. This mode is used to enter the cali-

bration counts into the data record. A data polarity signal is provided for a directly coupled printer via U5-F. The latch U8-B controls the radon counter's minute timer, causing it to wait from the time of the tape move until the next minute mark before resuming the counting cycles. The gate U10-D is a CMOS-TTL interfacing inverting driver used to set ACC PRINT, a TTL latch in the Mux unit. This is done for the first count of a new sample. U10-D's information input comes from a decoding circuit on the Data Board. The gate U10-A tests to see if at least one of the twisted pair data wires is being held low by the Pulse Handling Board. If not, something is wrong and LED #8 is turned on. The minute-mark generating circuit is similar to that described for the WIND VANE, where it is used to generate seconds. The moderated 60-Hz signal gets shaped by U6-A, a Schmitt trigger. The square wave is used to clock the 12-bit binary counter U1. A total of 3,600 pulses is decoded by U2-A, which activates the one-min. pulse shaper circuit and driver U6-B. Although the feedback loop immediately resets U1 to zero, the pulse is sustained for 500 µs by the 0.0015 µf capacitor. The onboard button B3 is to manually synchronize the minute mark with some other timer, a task which can also be done electronically at pin 19. A provision is made for an EXTERNAL START signal at pin 14, to secure cycle lengths other than those available from the DIP switches. (Cycles could be greater than 90 min., or as short as 11 min. when EXTERNAL STOP at pin 13 is used to secure 5 or 10 min. samples.) The use of pins 13 and 14 allows another unit, such as a microprocessor, to control the sample and cycle length. Pulling pin 12 low will shut off the blower and start moving the tape. The Data Board is set up to immediately print out the counts when counting is halted due to tape motion. Therefore, shorter counting durations than 10 min. may be obtained by momentarily pulsing pin 12 low. However, counting does not resume until the following min. mark, which could be injected by momentarily pulling pin 19 low.

Data Board

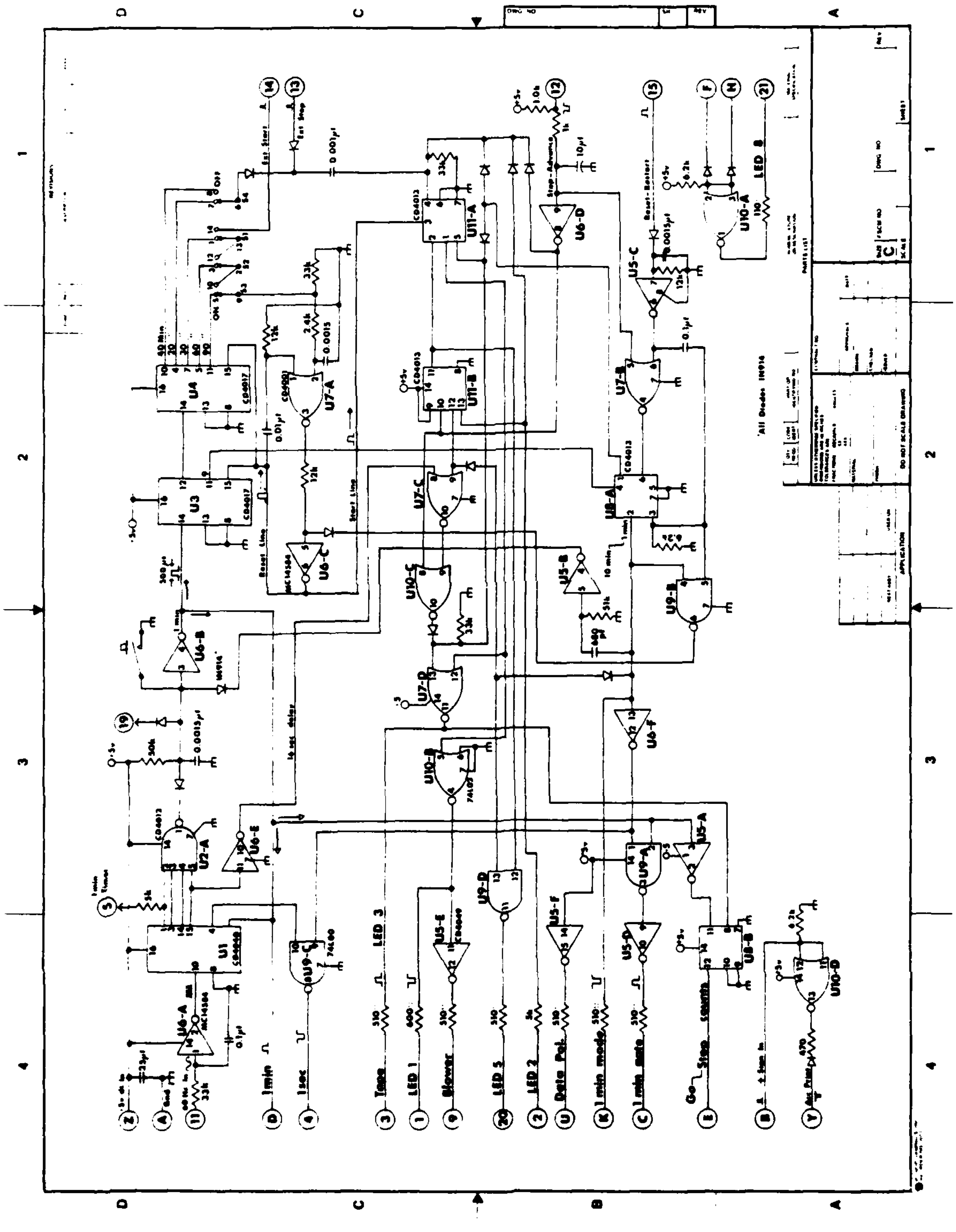
The data signals enter the board at pins F and H and are routed to U16, which converts them to conventional TTL logic. From U16 they go directly to U15, the analog output circuit one shot, and U17, the first of a series of cascaded decade digital counters. The analog one shot will give a pulse width which is adjustable by the 50KΩ trimpot. Its output goes to the parallel drivers U12-A and B, and their outputs are integrated by the 100 µf capacitor. The trimpot can be adjusted so that pCi/m^2 of atmospheric radon can be read out at the analog output pin (J) directly in millivolts. Radioactive decay causes the analog output to decrease with time from the moment a new sample is advanced between the counting tubes. Therefore, the trimpot is actually adjusted so the millivolt level of the beginning peak is the true value of pCi/m^2, and the rest of the trace has to be corrected for radioactive decay.

Although the counters also continually receive pulses, their counting duration is under the control of the minute counter U13.

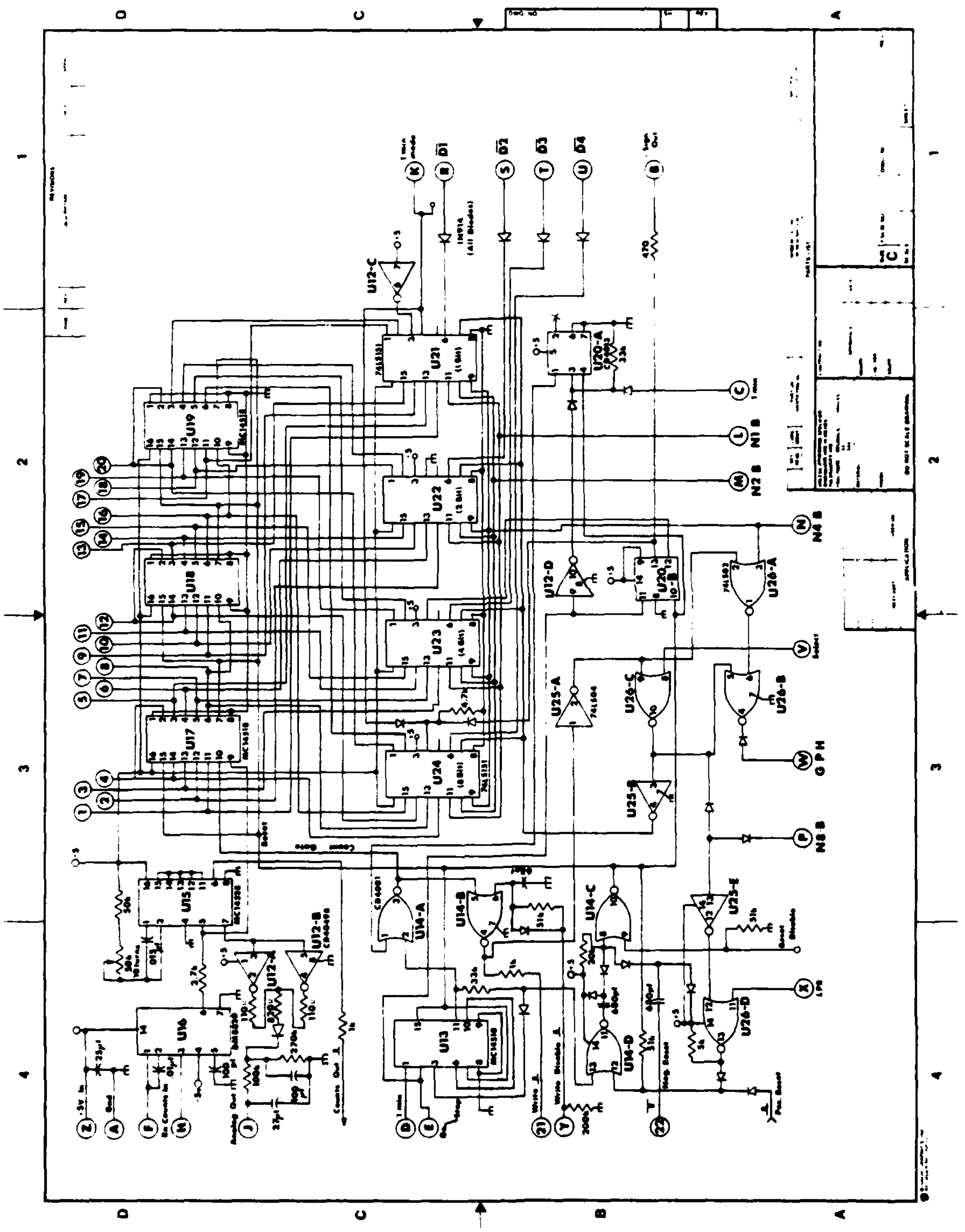
After 10 min. of counting, gate U14-A is closed, disabling the counters (U17-U19) and giving a WRITE command to pin 21, which is a direct control line to a dedicated printer. When the printer sees this signal it secures the data presented to it on pins 1-20 and B, and pins Y and U on the control board. Upon securing the data the printer begins printing it, and returns a high BUSY signal to pin 22. When the Busy signal falls low, the Reset Line is activated by U14-C, which is coupled back to U14-D to form a boot strap loop to sustain the pulse a short time. The Reset pulse zeroes the counters and the timer, U13. Immediately the counters will start accumulating, since U14-A is opened when U13 resets. Almost instant reset/restart after 1/2 μs delay from the rising edge of the busy signal can be achieved by returning the Busy signal to pin Y and connecting pin 21 to 22. A high on pin Y would cause (21) to go low, which would then pulse U14-(8) low due to the 680 pf capacitor leading in from pin 22, starting a reset cycle.

U21-U24 are the multiplex transmitter chips. A write command enters the Mux port logic via U25-A. This activates U26-B (via U-26A since U26-(5) is still held low by U26-C), which sends out a G/P/H signal to start a scan. As the scan progresses N4-B (N) goes high for the last half of each transmitted line, turning off the G/P/H signal from this unit at that time. This continues until this port is "selected" by V going low. At that time U26-C is opened, which activates U25-B and puts the data transmitter chips on the bus. U26-C also opens U26-B via pin 5, holding G/P/H low at the end of a data line transmission. A low G/P/H at that time induces a print cycle in the Mux Controller, and the subsequent return of the LPR signal at pin X will cause the Reset function (on this board) to operate from U26-D. (Note that since we need only print one line of data from this unit, pin P is not connected to the diode going to U26-(13). Therefore, the LPR signal will trigger a Reset when the first line is printed.) The reset function will now cause the local Mux Interface Logic to disengage the G/P/H line allowing the Mux Controller to eventually advance to the next port. The resetting is fast enough that this unit does not interfere with the thumbwheel data, which is inserted as the second line of print from this input port.

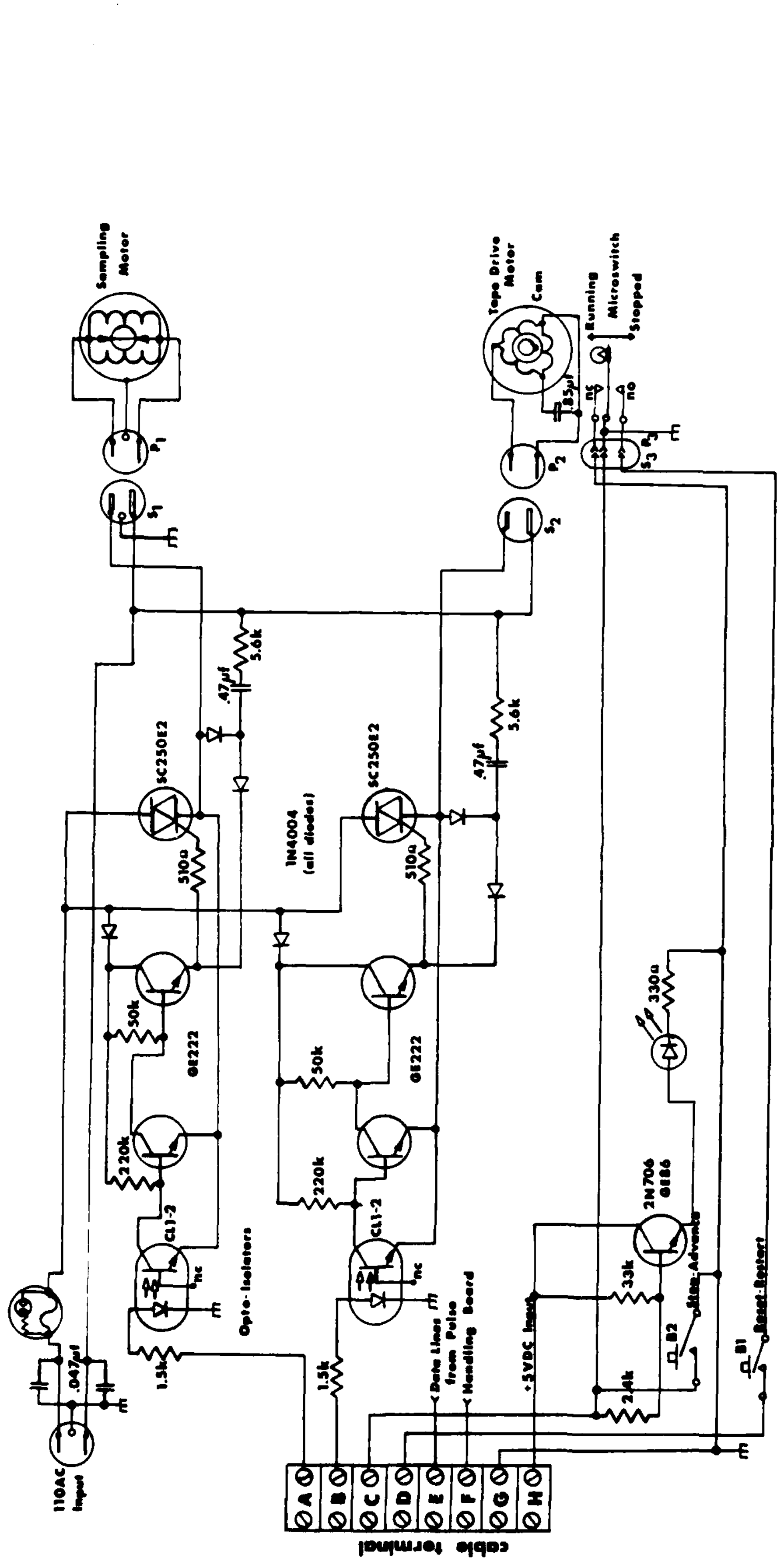
Latch U20-B holds the signal which flags the first line of print for a new sample. The information is fed as a + sign both to a dedicated printer at pin B, and directly to the Mux transmitter chips at U24-4 and U23-4. Latch U20-A is used to cause one data print to occur when the tape moves, by triggering gate U14-A. The 1-Min. Gate signal also triggers this gate for a print when the Control Board is in the 1-min. mode. The diode loop from U13-(3) to U14-(13) exists to reset the unit if a Busy or Reset signal is not returned by some data recording unit within one minute from the time the 10 min. count is done, i.e. it resets at minute mark 11, starting a new count. Inverter U12-C feeds data polarity information into the Mux transmitters, while the signal at (K) properly positions the decimal point for either one or ten min. count modes, so that the counts can always be read as CPM.



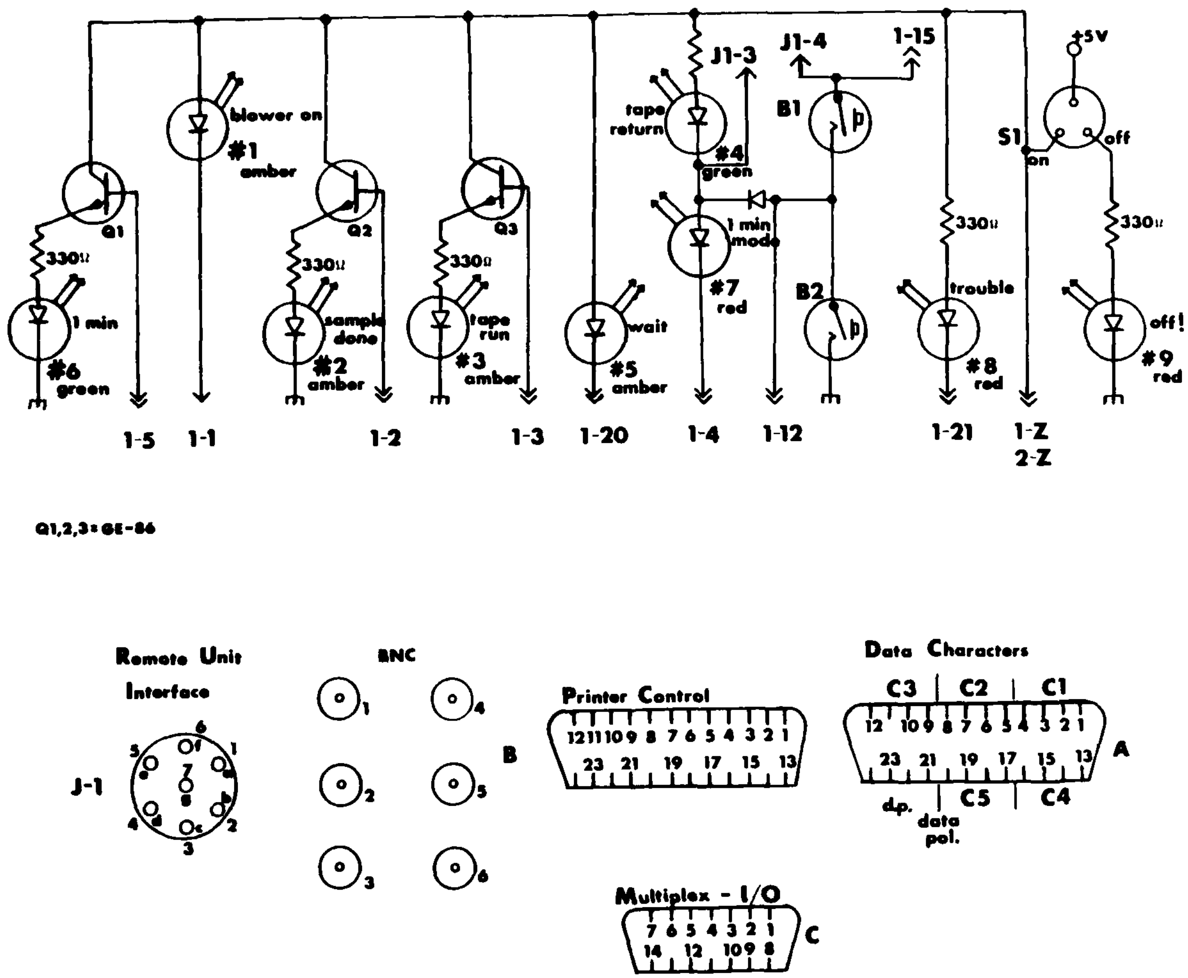
ARCAS Control Board



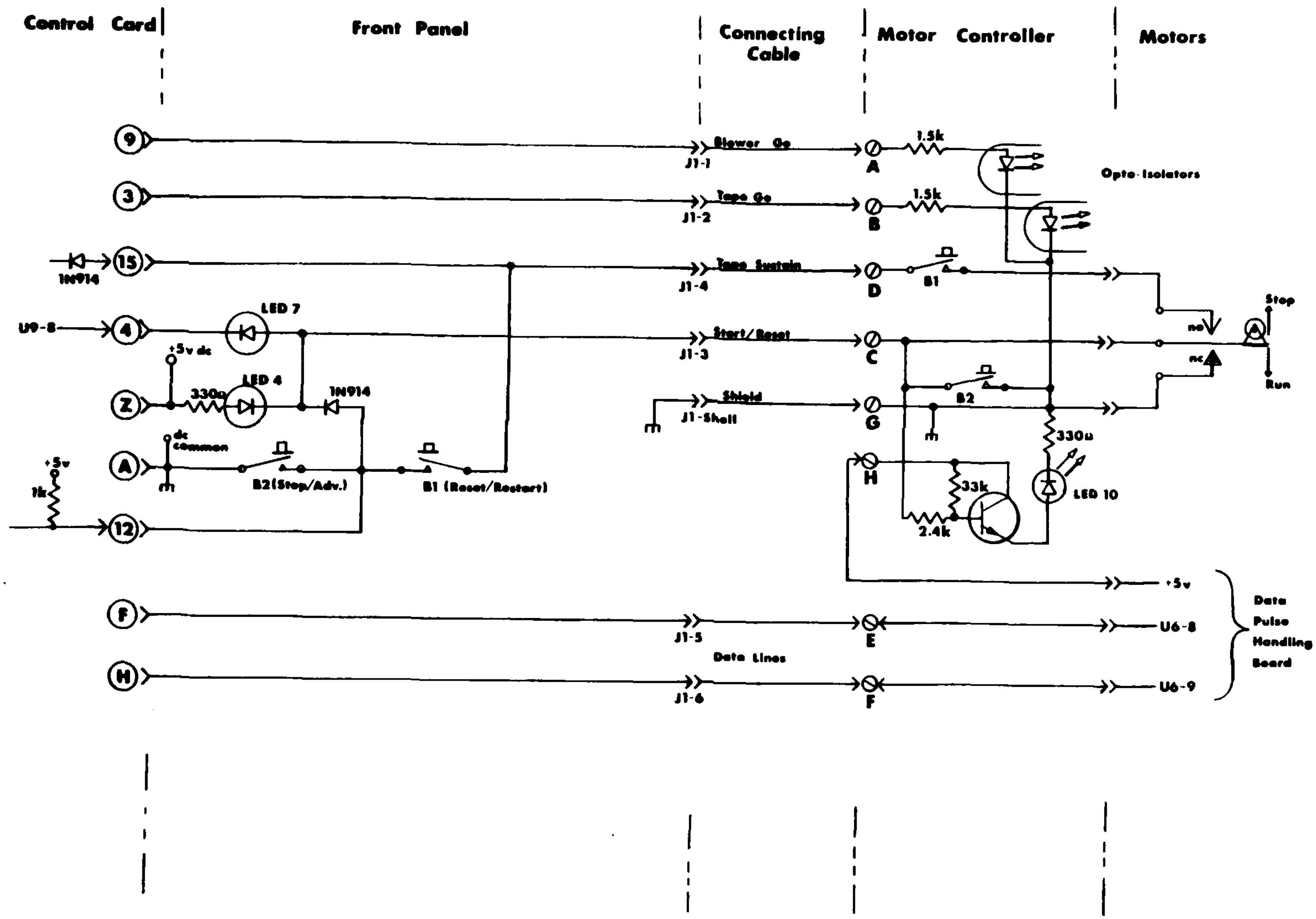
ARCAS Data Board



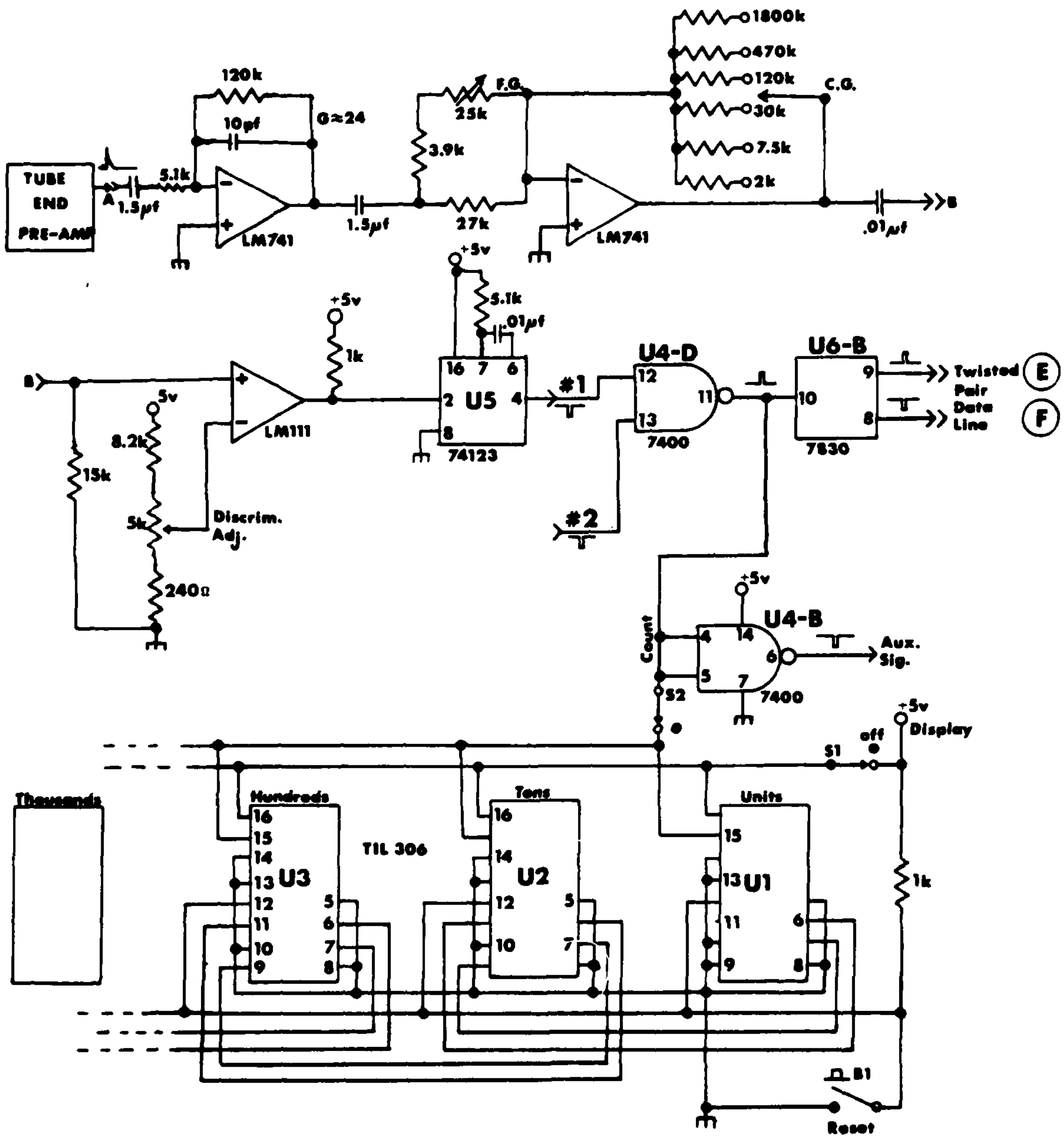
ARCAS Motor Control Board



ARCAS Front Panel Circuits and Rear Panel Plugs



ARCAS Interconnections



ARCAS Pulse Handling Board

END

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